US Army Corps of Engineers
Waterways Experiment Station

Technical Report CHL-97-25
August 1997

Model Study of the Confluence of San Juan Creek and Trabuco Creek, Orange County, California

Hydraulic Model Investigation

by Darla C. McVan

Prepared for County of Orange, Public Facilities and Resources Department

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3909 Halls Ferry Road
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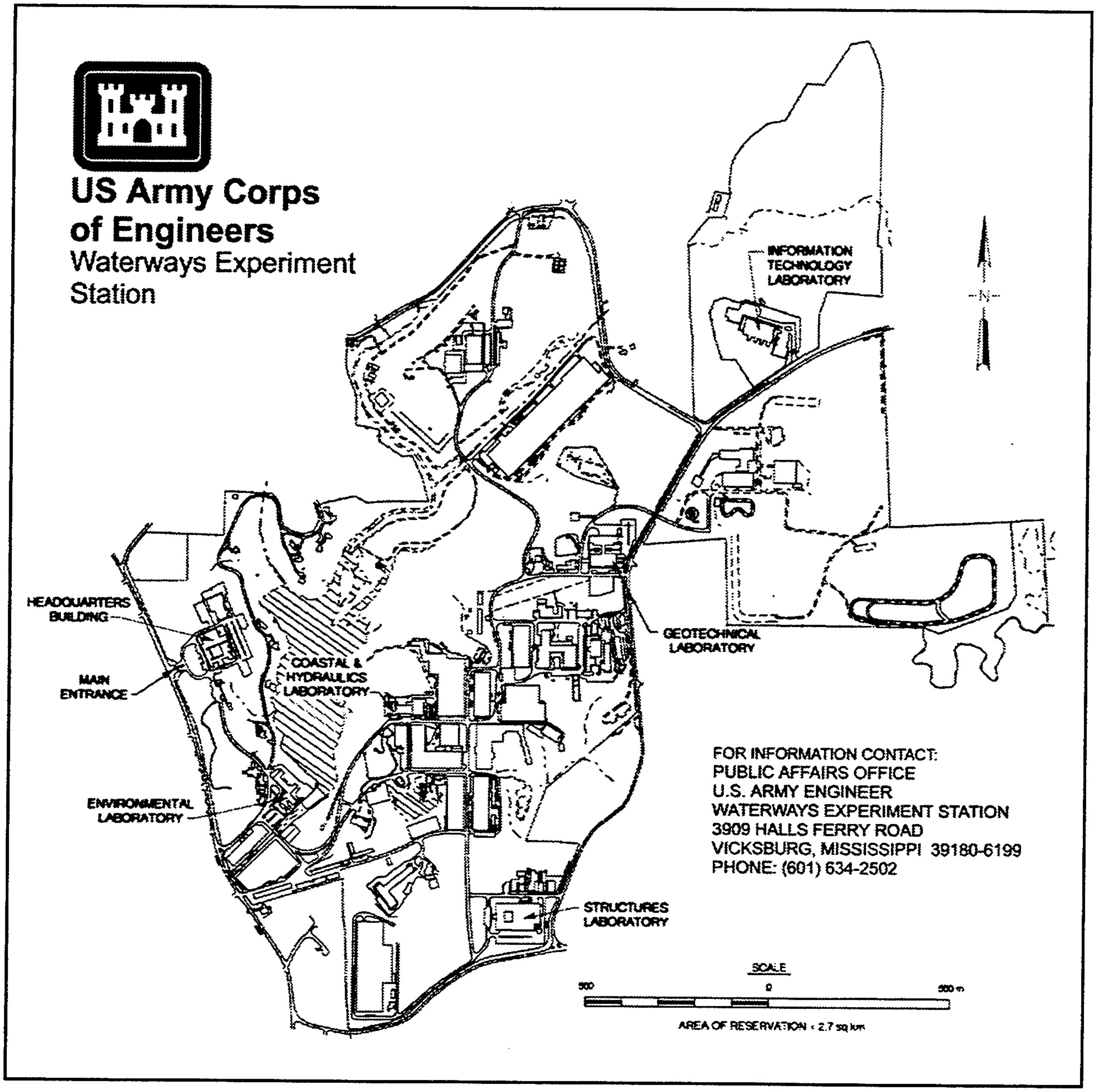
Final report

Prepared for County of Orange, Public Facilities and Resources Department
Santa Ana, CA 92703



Waterways Experiment Station Cataloging-in-Publication Data

McVan, Darla C.
Model study of the confluence of San Juan Creek and Trabuco Creek, Orange County, California : hydraulic model investigation / by Darla C. McVan ; prepared for County of Orange, Public Facilities and Resources Department.
199 p. : ill. ; 28 cm. — (Technical report ; CHL-97-25)
Includes bibliographic references.
1. Hydraulic models. 2. Stream channelization — California — Orange County. I. United States. Army. Corps of Engineers. II. U.S. Army Engineer Waterways Experiment Station. III. Coastal and Hydraulics Laboratory (U.S. Army Engineer Waterways Experiment Station) IV. Orange County (Calif.). Public Facilities and Resources Dept. V. Title. VI. Series: Technical report (U.S. Army Engineer Waterways Experiment Station) ; CHL-97-25.
TA7 W34 no.CHL-97-25

Contents

Preface

The model investigation reported herein was authorized by the Orange County Environmental Management Agency Public Works, Orange County Flood Control District (OCFC), Santa Ana, CA, on 9 June 1992. The study was conducted by personnel of the Hydraulics Laboratory (HL), U.S. Army Engineer Waterways Experiment Station (WES), during the period of August 1992 to September 1994.

All studies were conducted under the general supervision of Messrs. F. A. Herrmann, Jr., Director of the Hydraulics Laboratory; R. A. Sager, Assistant Director of the Hydraulics Laboratory; and G. A. Pickering, Chief of the Hydraulic Structures Division (HSD), HL. The experiments were conducted by Ms. D. C. McVan, of the Hydraulic Analysis Branch, HSD, and Messrs. R. Bryant, Jr., K. Pigg, and E. L. Jefferson of the Spillways and Channels Branch, HSD, and Mr. V. E. Stewart, of the Locks and Conduits Branch, HSD, under the direct supervision of Messrs. B. P. Fletcher, Spillways and Channels Branch, and N. R. Oswalt, Chief of the Spillways and Channels Branch, HSD. This report was prepared by Ms. McVan. Data analysis assistance during this study was provided by Ms. Janie M. Vaughan, HSD, and Mr. Brian Williams, Computer Sciences Corporation, Vicksburg, MS.

The model was constructed by Messrs. E. Lee, C. Hopkins, J. Lyons, and M. Simmons, of the Engineering and Construction Services Division (E&CSD), WES, under the direct supervision of Mr. E. Case, Chief of the Model Shop, E&CSD, and by members of the construction crew led by Mr. C. Drayton, crew foreman, Construction Services, E&CSD, under the supervision of Mr. T. Lee, Chief of Construction Services, E&CSD.

Messrs. Jerry D. Sterling and Lance M. Natsuhara from the Orange County Flood Control District and Messrs. Tom Boyd and Tom Bernard, representatives from Boyle Engineering Corporation, which was contracted for the railroad bridge design, visited WES during the study to discuss experiment results and to correlate these results with concurrent design works.

Dr. Robert W. Whalin was Director of WES at the time of publication of this report.

Conversion Factors, Non-SI to SI Units of Measurement

Non-SI units of measurement used in this report can be converted to SI units as follows:

Multiply	By	To Obtain
acres	4,046.87	square meters
cubic feet per second	0.028317	cubic meters per second
degrees (angle)	0.017453	radians
feet per second	0.3048	meters per second
miles (US statute)	1.609347	kilometers
square feet	0.092903	square meters
square miles	2.589998	square kilometers

1 Introduction

The Prototype

San Juan Creek is located in the southerly portion of Orange County, California. The stream's headwaters start in the Cleveland National Forest and outlet into the Pacific Ocean immediately downcoast of Dana Point Harbor (Figure 1). San Juan Creek is approximately 27 miles (43 km) long, rises to an elevation of approximately 5,700[1] and encompasses a drainage area of 175 square miles (453 sq km). Trabuco Creek is a tributary to San Juan Creek. Its headwaters also originate in Cleveland National Forest at about the same elevation as San Juan Creek. Trabuco Creek is approximately 24 miles (39 km) long with a drainage area of 54 square miles (140 sq km). The design discharges for these creeks are 41,900 cfs and 22,600 cfs (1,186 cu m/sec and 640 cu m/sec), respectively, for a combined total (recognizing the difference in hydrologic peaks) of 59,000 cfs (1,671 cu m/sec).

The Orange County Environmental Management Agency Public Works, Orange County Flood Control District (OCFC), Santa Ana, California, has proposed improving the hydraulic design of the confluence of San Juan and Trabuco Creeks, located in San Juan Capistrano, Orange County, California. The existing trapezoidal channel has concrete-lined side slopes (1V:2H) with a sand and gravel bottom. The confluence angle is 20 degrees (0.349 rad) with Trabuco Creek entering San Juan Creek on the inside of a curve. The planned improvements consist of widening the invert of the San Juan channel from 150 to 192 ft (46 to 59 m), steepening the left embankment[2] (east levee) from a 1V:2H slope to a 1V:1H slope and lining the slope with reinforced concrete, raising both the left and right (west levee) embankments roughly 3 to 5 ft (0.9 to 1.5 m) with retaining walls on the outer side of the levee to accommodate right-of-way limitations, removing and relocating various access ramps, and realigning the present railroad bridge.

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[1] All elevations (el) cited herein are in feet referenced to the National Geodetic Vertical Datum (NGVD). To convert to meters, multiply by 0.3048.

[2] The U.S. Army Corps of Engineers designates the left and right banks as looking in the downstream direction.

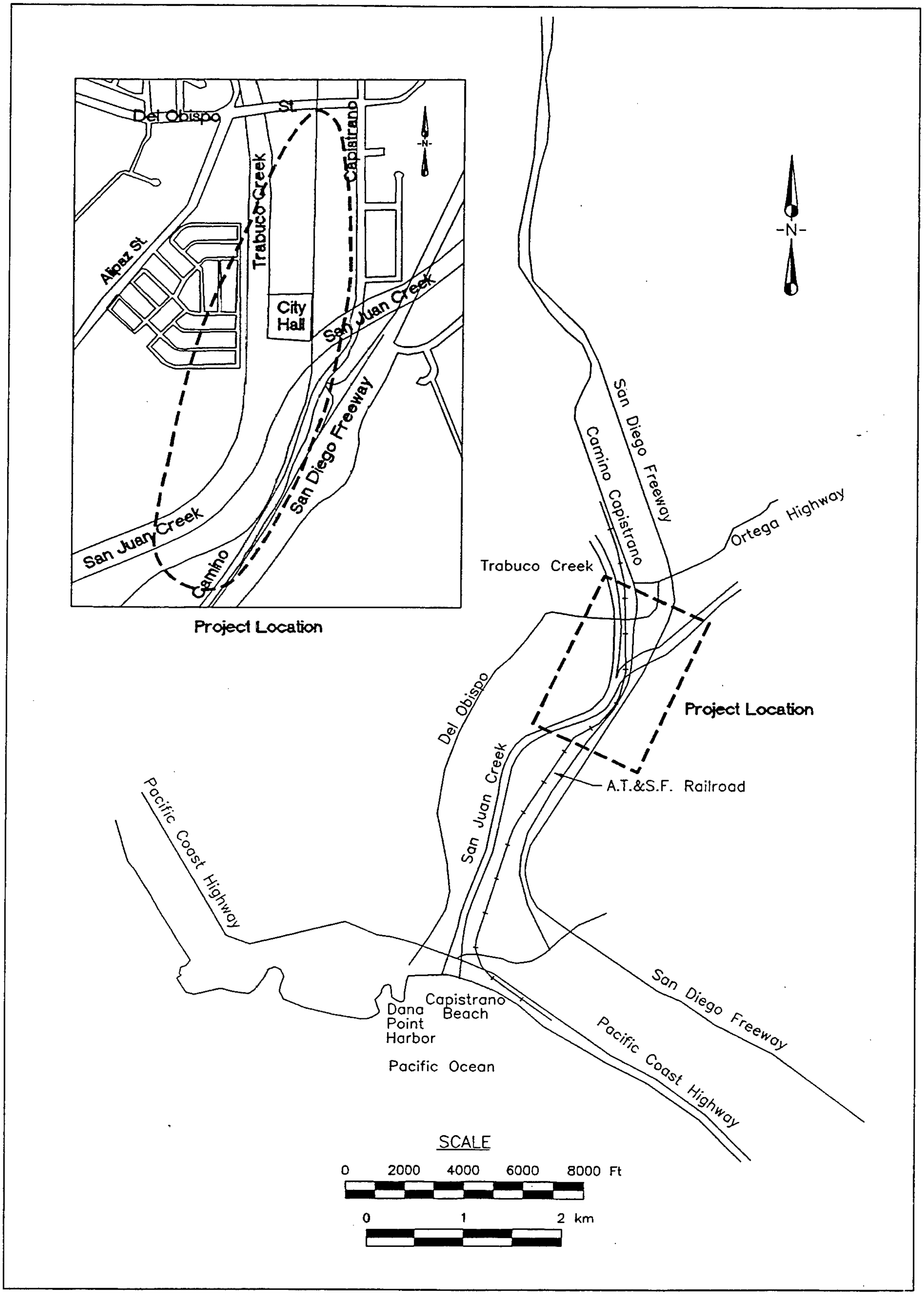


Figure 1. Vicinity and location map

Purpose and Scope of Model Investigation

The purpose of the study was to investigate the hydrodynamic characteristics of the proposed modifications at the confluence of the San Juan and Trabuco Creeks. A physical model study of the proposed channels was desired to support design assumptions and provide direction for solution of design issues. Specifically, the model study was to determine:

a. Flow conditions, water-surface profiles, and velocities for the proposed channel improvements.

b. Optimum length and location of a proposed training wall.

c. Flow patterns, flow profiles, and potential scour patterns in the channel and near the structures.

d. Flow patterns around the existing and proposed Del Obispo Bridge crossing Trabuco Creek.

e. Flow patterns around the Camino Capistrano Bridge, including any adverse impacts of the proposed bike trails.

f. The need for bottom stabilization.

g. Flow patterns around the existing and proposed railroad bridge crossing San Juan Creek.

2 The Model

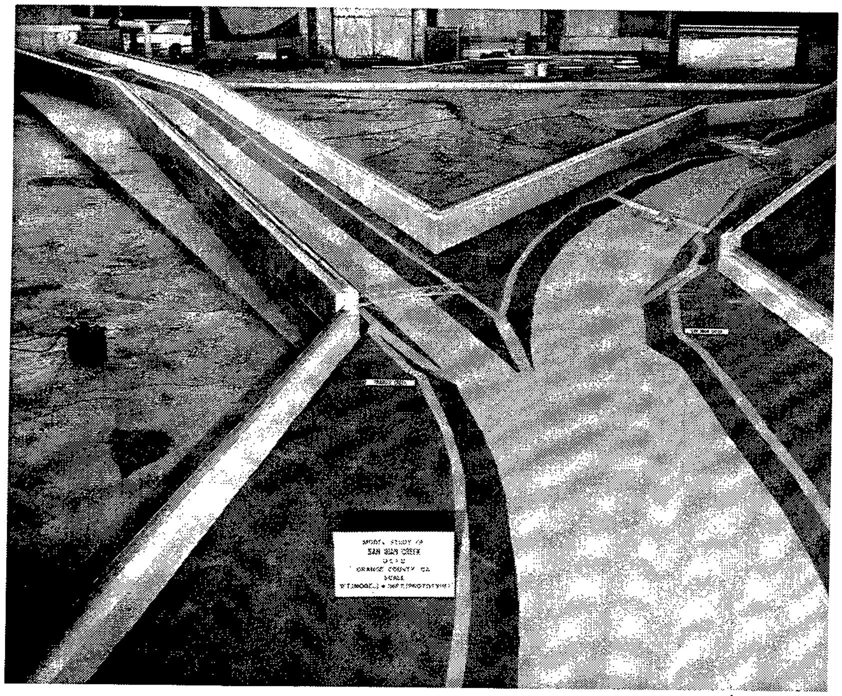
Description

The model was constructed to a scale of 1:36 and reproduced approximately 5,200 ft (1,585 m) of San Juan Creek, 100 ft (30 m) upstream of the San Diego Freeway, and approximately 2,900 ft (884 m) downstream of the confluence (sta 150+00 to sta 98+00), and 5,100 ft (1,550 m) of Trabuco Creek (sta 51+00 to its confluence with San Juan Creek) (Figure 2a). The entire channel was molded in sand and cement mortar to sheet-metal templates. The prototype Manning's roughness coefficient was determined to be $n = 0.022$.[1] This value was scaled to a model Manning's roughness coefficient, $n = 0.012$, which is the roughness coefficient for cement mortar. (See "Scale Relations" section to see how the model scale was developed.) Later the fixed-bed channel invert was replaced with cohesionless material (fine pea-sized gravel) (Figure 2b) and then a mixture of sand and gravel to obtain scour patterns.

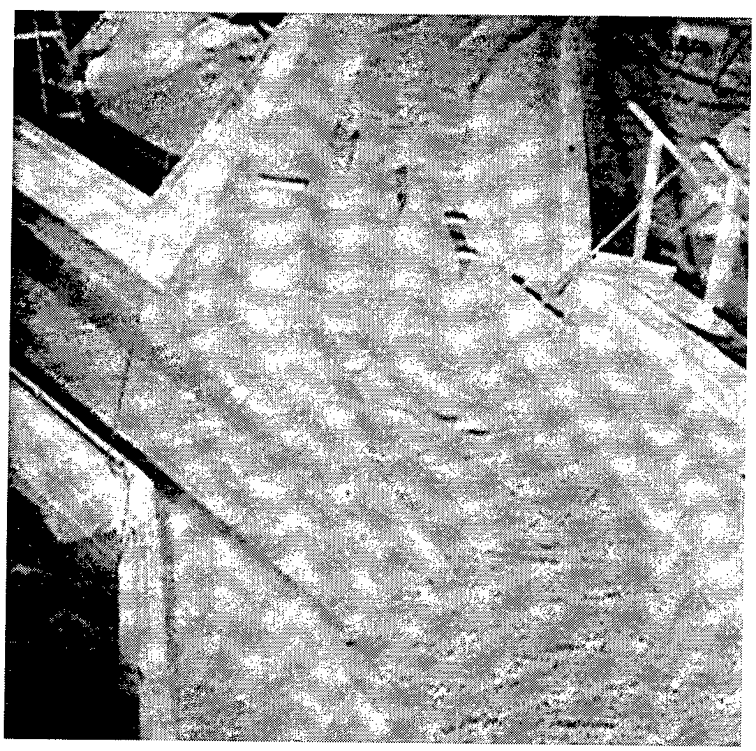
Model Appurtenances

Flow to the model was supplied from a sump by pumps through a circulating system. Discharges were measured by elbow meters (calibrated in place) installed in the flow lines and were baffled before entering the model. Velocities were measured with pitot tubes that were mounted to permit measurement of current velocity from any direction and at any depth. Water-surface elevations were measured with point gages. Different designs, along with various flow conditions, were documented photographically.

[1] Ven Te Chow. (1959). *Open-channel hydraulics*. McGraw-Hill, New York.



a. Type 1 design, fixed bed



b. Type 7 design, gravel bed

Figure 2. San Juan Creek, looking upstream at the confluence with Trabuco Creek

Scale Relations

The accepted equations of hydraulic similitude, based on Froudian criteria, are used to express mathematical relations between the dimensions and hydraulic quantities of the model and prototype. General relations for transference of model data to prototype equivalents are given in the following tabulation. Model measurements of discharge, water-surface elevations, and velocities can be transferred quantitatively to prototype by the scale relations.

Characteristic	Dimension[1]	Scale Relations Model:Prototype
Length	$L_r = L$	1:36
Area	$A_r = L_r^2$	1:1,296
Velocity	$V_r = L_r^{1/2}$	1:6
Time	$T_r = L_r^{1/2}$	1:6
Discharge	$Q_r = L_r^{5/2}$	1:7,776
Roughness coefficient	$N_r = L_r^{1/6}$	1:1.82

[1] Dimensions are in terms of length.

3 Tests and Results

Initial Tests (Type 1 Design)

The initial experiments were conducted with a fixed channel invert to observe general flow conditions in the channels with the existing channel design of San Juan Creek from sta 150+00 to sta 127+30, and the proposed channel design from sta 127+30 to sta 98+00, and with the existing channel design of Trabuco Creek (Plate 1). The fixed-bed channel simulated a Manning's *n* of 0.022. These experiments were conducted using various flow combinations including the design discharges (San Juan Creek Q_{sj} 42,000 cfs (1,176 cu m/sec) and Trabuco Creek Q_{tr} 17,000 cfs (476 cu m/sec)), unbalanced discharges (San Juan Creek 35,000 cfs (980 cu m/sec) and Trabuco Creek 5,000 cfs (140 cu m/sec)), and balanced discharges (San Juan and Trabuco Creeks 17,000 cfs (476 cu m/sec)).

Design discharges

Flow conditions observed in the San Juan Creek for the design discharges indicated that the flow was contained within its banks both upstream and downstream of the confluence. However, at the confluence, flow spilled over into Trabuco Creek along the right embankment (west levee) at sta 134+00 (Photo 1a). Flow overtopped the left embankment (east levee) between sta 133+00 and sta 126+50 (Photo 1a). Standing waves of approximately 2 to 3 ft (0.6 to 0.9 m) in height (measured from peak to trough) were observed downstream of the railroad bridge piers and were created by the bridge piers (Photo 1b). Water-surface profiles recorded for the design discharges in both San Juan (42,000 cfs (1,176 cu m/sec)) and Trabuco (17,000 cfs (476 cu m/sec)) Creeks are shown in Plates 2 and 3. Water-surface elevations used to plot the water-surface profiles are given in Table 1. Velocities measured in Trabuco Creek 1 ft (0.3 m) above the bottom are shown in Plates 4 and 5 and in San Juan Creek, Plates 6 and 7. Bottom velocities measured at the confluence are shown in Plate 8. Oblique standing waves were observed between the San Diego Freeway bridge piers, and the surface flow concentrated in the center of the bridge piers as shown by the confetti in Photo 2a. A standing wave was

observed originating along the left bank (east levee) at sta 126+50 and extending diagonally toward the right bank (west levee) (Photo 1a). This wave was caused by the abrupt expansion of the channel width from sta 127+30 to sta 126+50 (Photo 1a). A small standing wave was observed at the nose of the confluence at sta 128+00 and is shown in Photo 1a. The access road on San Juan Creek (Photo 1b) was completely submerged and did not affect flow conditions. Satisfactory flow conditions were observed in Trabuco Creek upstream from the junction with San Juan Creek for the design discharges. Four existing grade stabilizers, with grouted rock attached to the channel slopes, are located at sta 50+37, sta 42+75, sta 30+50, and sta 18+25. The water-surface profile (Plate 3) indicates that the flow depth increases upstream of each grade stabilizer and decreases downstream. Oblique standing waves observed downstream of each grade stabilizer were created by the grouted rock "wings" (Photo 3a). For the design discharges, the flow depth in Trabuco Creek increased significantly at the confluence (Plate 3), and small standing waves were observed due to the overflow from San Juan Creek (Photo 1a). The access road on Trabuco Creek at the confluence also contributed to the generation of standing waves (Photo 1a).

Unbalanced discharges

For the unbalanced discharges, the flow conditions observed for both San Juan (35,000 cfs (980 cu m/sec)) and Trabuco (5,000 cfs (140 cu m/sec)) Creeks were similar to those observed for the design discharges. Water-surface profiles recorded for San Juan and Trabuco Creek are shown in Plates 9 and 10, and water-surface elevations are given in Table 2. Bottom velocities for San Juan and Trabuco Creeks are shown in Plates 11-15. Flow from San Juan Creek spilled over the right embankment (west levee) and into Trabuco Creek and over the left embankment (east levee) at sta 132+00 (Photos 4a and 5a). Oblique standing waves were observed between the San Diego Freeway bridge piers in San Juan Creek (Photo 2b) and downstream of the grouted rock grade stabilizers in Trabuco Creek (Photo 3b). Standing waves of approximately 1 to 2 ft (0.3 to 0.6 m) were observed downstream of the railroad bridge piers (Photo 4a), and a diagonal standing wave extending across the channel was observed beginning at sta 126+50 (Photo 5a). Flow from San Juan Creek forced the flow from Trabuco Creek to hug the right embankment in the confluence, as shown in Photos 4a and 5a. Both access roads on San Juan (Photo 4a) and Trabuco Creeks (Photo 5a) contribute to the standing waves observed at the confluence (Photo 5a).

Balanced discharges

Flow was contained within the banks in San Juan Creek for the balanced discharges (17,000 cfs (476 cu m/sec) in both San Juan and Trabuco Creeks). Water-surface profiles for San Juan and Trabuco Creeks are shown in Plates 16 and 17, respectively, and the water-surface elevations are given in Table 3.

Standing waves created by the railroad bridge piers (Photo 4b) and oblique standing waves created by the San Diego Freeway bridge piers (Photo 2c) were observed downstream of the bridge piers. Oblique standing waves were also observed downstream of the grouted rock grade stabilizers (Photo 3c). A prominent oblique standing wave was observed in Trabuco Creek at the confluence and was caused by the access road and the nose of the confluence (Photo 5b). The access road on San Juan Creek upstream of the confluence also contributed to the standing waves downstream of the railroad bridge piers (Photo 4b).

Proposed Channel Improvements (Type 2 Design)

The experiments for the type 2 design were conducted to observe general flow conditions in the channel with the existing channel design of San Juan Creek from sta 150+00 to sta 137+00, the proposed channel design from sta 137+00 to sta 98+00, and the existing channel design of Trabuco Creek (Plate 18). These experiments included investigation of the proposed design of the railroad bridge piers (four debris nose bridge piers concentric to the center line of the channel), relocation of an access road from sta 130+00 to sta 134+00 on San Juan Creek and from sta 46+00 to sta 49+00 on Trabuco Creek, removal of an access road at sta 16+00 on Trabuco Creek, and adding a bike trail at sta 134+00 on San Juan Creek. The slope of the invert was also modified on San Juan Creek between stations 136+00 and 114+00 according to the proposed plans provided by CALTRANS (California Transportation). A typical debris nose bridge pier is shown in Figure 3. Experiments were conducted using the design discharges (San Juan Creek 42,000 cfs (1,176 cu m/sec) and Trabuco Creek 17,000 cfs (476 cu m/sec)), unbalanced discharges (San Juan Creek 35,000 cfs (980 cu m/sec) and Trabuco Creek 5,000 cfs (140 cu m/sec)), and balanced discharges (San Juan and Trabuco Creeks 17,000 cfs (476 cu m/sec) each).

Design discharges

Flow conditions observed in San Juan Creek for the design discharges indicated that the flow was contained within its banks. Water-surface profiles recorded for the design discharges in both San Juan (42,000 cfs (1,176 cu m/sec)) and Trabuco (17,000 cfs (476 cu m/sec)) Creeks are shown in Plates 19 and 20. Water-surface elevations used to plot the water-surface profiles are given in Table 4. Velocities measured 1 ft (0.3 m) above the bottom in San Juan and Trabuco Creeks are shown in Plates 21-23. Standing waves of approximately 4 to 5 ft (1.2 to 1.5 m) in height were created by the railroad bridge piers (Photo 6a). A diagonal standing wave (right bank to left bank) formed beginning at approximately sta 134+30 and ending at sta 132+70. This

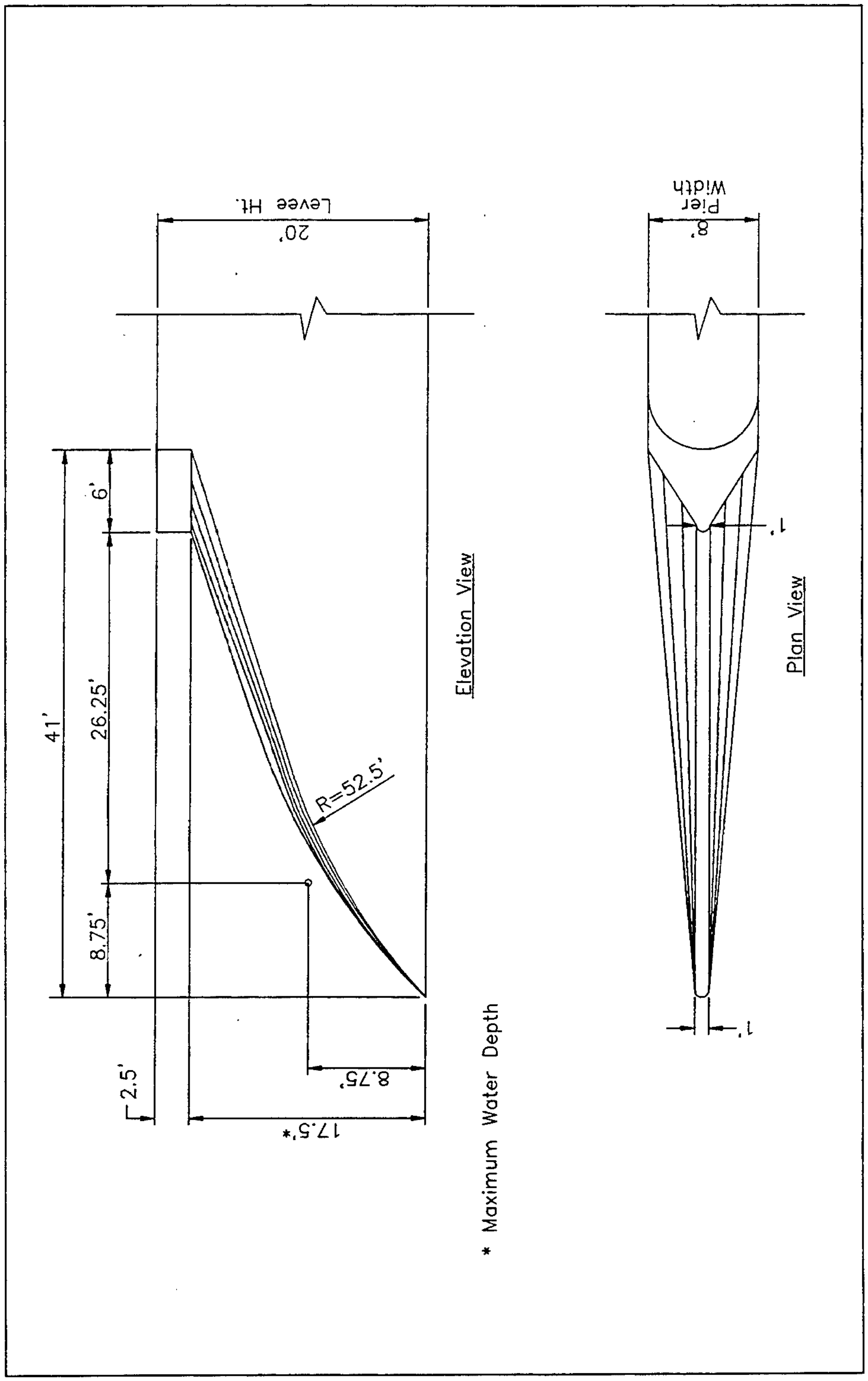


Figure 3. Typical debris nose bridge pier. To convert dimensions given in feet to meters, multiply by 0.3048.

wave was caused by flow separation[1] that occurred on the left bank (east levee) at the access road between sta 134+50 and sta 132+00 and forced the flow toward the right bank (west levee). The flow velocity decreased between the first railroad bridge pier and the right bank and the fourth railroad bridge pier and the left bank, which caused the flow to concentrate in the center of the channel between railroad bridge piers two and three (Plate 21). This caused the flow to accelerate and also contributed to the generation of the standing waves shown in Photo 6a. The nose of the confluence was completely submerged and did not adversely affect flow conditions (Photo 6a). Satisfactory flow conditions were observed downstream of the confluence at approximately sta 124+00. Satisfactory flow conditions were also observed in Trabuco Creek upstream of the junction with San Juan Creek. The grouted rock wings attached to the channel slopes at the four grade stabilizers (sta 50+37, 42+47, 30+50, and 18+25, Plate 20 and Photo 7a) were removed for the type 2 design. The oblique standing waves observed downstream of the grouted rock wings with the type 1 design were not observed with the type 2 design. A diagonal standing wave was observed beginning on the right bank at the access road at sta 47+00 and extending toward the left bank at sta 45+75 (Photo 7a). This wave was caused by an expansion of the flow due to the access road. The flow became satisfactory as it approached the Del Obispo bridge piers.

Unbalanced discharges

For the unbalanced discharges, the flow conditions were documented for both San Juan (35,000 cfs (980 cu m/sec)) and Trabuco (5,000 cfs (140 cu m/sec)) Creeks. Water-surface profiles are shown in Plates 24 and 25, and water-surface elevations are given in Table 5. Bottom velocities are shown in Plates 26-28. Standing waves of approximately 2 to 3 ft (0.6 to 0.9 m) were observed downstream of the railroad bridge piers, and a diagonal standing wave extending across the channel was observed beginning at sta 134+10 (Photo 6b). Flow separation occurred on the left bank at the access road between sta 134+50 and sta 132+00 and forced the flow toward the right bank. Flow from San Juan Creek forced the flow from Trabuco Creek in the confluence to hug the right embankment; however, flow from San Juan Creek stayed close to the left embankment (Photo 6b).

Velocities decreased between the first railroad bridge pier and the right bank and the fourth railroad pier and the left bank (Plate 26). The nose of the confluence had no adverse effect on the hydraulic performance (Photo 6b). A diagonal standing wave beginning at the access road at sta 47+00 and extending

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[1] Flow separation is the "separation of moving fluid from boundary surfaces" (John K. Vennard and Robert L. Street. (1982). *Elementary fluid mechanics*. 6th ed., Wiley, New York). Basically, it is when an unfavorable pressure gradient penetrates the boundary layer and produces a force opposing the motion of fluid; a large gradient will cause the moving fluid near the wall to be brought to rest and begin to accumulate, forcing the "live" flow outward from the surface.

across the channel to sta 46+00 was observed in Trabuco Creek (Photo 7b). Satisfactory flow conditions were observed downstream of the confluence at sta 124+00 and in Trabuco Creek.

Balanced discharges

Flow conditions observed for the balanced discharges (San Juan Creek 17,000 cfs (476 cu m/sec) and Trabuco Creek 17,000 cfs (476 cu m/sec)) were also documented. Water-surface profiles are shown in Plates 29 and 30, and bottom velocities are shown in Plates 31-33. Water-surface elevations are provided in Table 6. Standing waves created by the railroad bridge piers were observed downstream from the bridge (Photo 6c). Flow separation was observed on the left embankment at sta 134+50. A small oblique standing wave was observed in Trabuco Creek at the confluence (Photo 6c). A diagonal standing wave was observed in Trabuco Creek beginning at sta 47+00 and extending across the channel to sta 45+75 (Photo 7c). Flow conditions were satisfactory in Trabuco Creek and downstream of the confluence beginning at sta 120+00.

Proposed Training Walls

Experiments were conducted with various training wall designs installed at the confluence to determine if the flow concentration and the standing waves at the confluence could be eliminated or reduced. These designs were subjected to various discharge combinations: the design discharges (San Juan Creek 42,000 cfs (1,176 cu m/sec) and Trabuco Creek 17,000 cfs (476 cu m/sec)), balanced discharges (San Juan and Trabuco Creeks 17,000 cfs (476 cu m/sec) each), and unbalanced discharges (San Juan Creek 8,000 cfs (224 cu m/sec) and Trabuco Creek 17,000 cfs (476 cu m/sec)).

Design discharges

Training walls 100 and 200 ft (30 and 60 m) long (type 3 and 4 designs) were installed at the confluence and are shown in Plates 34 and 35. The top of the training walls extended above the surface of the water approximately 18 ft (5 m). The training walls had no significant positive effect on the flow conditions observed for the design discharges. The water depth upstream of the walls increased in San Juan Creek and the flow overtopped the right embankment (west levee) between sta 130+00 and 128+00. The training walls did not help to minimize the standing waves that were created by the railroad piers, and an oblique standing wave was observed on Trabuco Creek at sta 15+00. Flow conditions were observed with the 100-ft- (30-m-) long training wall positioned at a 10-deg (0.174-rad) angle with the nose of the confluence (type 5 design,

Plate 36), the natural angle created by the force of flow from San Juan Creek. The flow was contained within its banks; however, it did not minimize the standing waves created by the railroad bridge piers. The oblique standing wave observed on Trabuco Creek at sta 15+00 was reduced, but was still noticeable.

Balanced discharges

Flow conditions observed for the balanced discharges (San Juan and Trabuco Creeks 17,000 cfs (476 cu m/sec) each) were similar to the flow conditions observed for the design discharges. The training walls did not minimize the standing waves downstream of the railroad bridge piers, and an oblique standing wave was observed on Trabuco Creek at sta 15+00.

Unbalanced discharges

A very prominent standing wave was observed at the nose of the confluence with an unbalanced discharge combination of 8,000 cfs (224 cu m/sec) in San Juan Creek and 17,000 cfs (476 cu m/sec) in Trabuco Creek before the training walls were installed. The standing wave was considerably reduced after the training walls were installed.

Additional Channel Modifications

The OCFC provided additional channel modifications to improve the hydraulic flow conditions in San Juan Creek. These channel modifications, designated as the type 6 channel design, included removal of an access road at sta 134+00 on San Juan Creek, steepening the left embankment (east levee) from a 1V:1H slope to a vertical wall between sta 132+91 and 125+97 (the upstream transition from a 1V:1H slope to a vertical wall began at sta 134+95 and the downstream transition ended at sta 123+59), modifying the slope of the invert between stations 137+00 and 134+00 on San Juan Creek, attaching a debris nose to the bridge piers on Del Obispo Bridge on Trabuco Creek, and replacing the proposed four-pier railroad bridge with a proposed three-pier railroad bridge with debris nose bridge pier extensions concentric to the center line of the channel. The type 7 design was identical to the type 6 design except the pier extensions were removed (Plate 37). Experiments were conducted using the design discharges (San Juan Creek 42,000 cfs (1,176 cu m/sec) and Trabuco Creek 17,000 cfs (476 cu m/sec)), unbalanced discharges (San Juan Creek 35,000 cfs (980 cu m/sec) and Trabuco Creek 5,000 cfs (140 cu m/sec)), and balanced discharges (San Juan and Trabuco Creeks 17,000 cfs (476 cu m/sec) each).

Type 6 design

Design discharges. Flow conditions observed in San Juan Creek for the design discharges (San Juan Creek 42,000 cfs (1,176 cu m/sec)) indicate that the flow was contained within its banks. Visual experiments were conducted to determine the bridge pier extension's relative benefit to the hydraulic characteristics of the confluence. The pier extensions extended from sta 133+30 to sta 134+17 for the center pier and sta 132+25 to sta 134+17 for the left pier (Photo 8a). The right pier was not extended. A prominent standing wave that extended the width of the channel was observed at sta 134+00 and was induced by the change in slope of the channel's invert at sta 134+00 and the decrease in flow area from the pier widths (Photo 9a). Standing waves also occurred downstream from the railroad piers (Photo 10a). Flow separation occurred on the right bank at sta 134+50 and was created by the bike trail (Photo 8a). Flow conditions in the vicinity of the railroad bridge were better without the pier extensions (type 7 design). Therefore, water-surface and velocity profiles were not measured with the type 6 design.

Unbalanced discharges. Various flow conditions for the unbalanced discharges (San Juan Creek 35,000 cfs (980 cu m/sec) and Trabuco Creek 5,000 cfs (140 cu m/sec)) for the type 6 design are shown in Photos 8b-10b. Standing waves were observed downstream of the railroad bridge piers (Photo 8b), and a prominent standing wave that extends the width of the channel was observed at sta 134+00 (Photo 8b). Flow separation was observed on the right bank at sta 134+50 and was created by the bike trail (Photo 8b). Flow conditions for the unbalanced discharges were better without the pier extensions.

Balanced discharges. Various flow conditions for the balanced discharges (San Juan Creek and Trabuco Creeks 17,000 cfs (476 cu m/sec)) for the type 6 design are shown in Photos 9c and 10c. Standing waves were observed downstream of the railroad bridge (Photo 10c), and a standing wave expanding across the channel was observed at sta 134+00 (Photo 9c). Flow separation was observed on both the left and right banks at sta 135+00 and 134+50, respectively (Photo 10c). Flow conditions in the vicinity of the railroad bridge were better without the pier extensions.

Type 7 design

Design discharges. The type 7 design consisted of the type 6 design without the pier extensions (Plate 37). Water-surface profiles recorded for the design discharges in San Juan Creek (42,000 cfs (1,176 cu m/sec)) and along the railroad bridge piers are shown in Plates 38 and 39, respectively. Water-surface elevations used to plot the profiles are given in Tables 7 and 8. Velocities measured 1 ft (0.3 m) above the bottom in San Juan Creek are shown in Plates 40 and 41. Standing waves of approximately 4 to 5 ft (1.2 to 1.5 m) in height were observed downstream of the railroad bridge piers and were created by the railroad bridge piers (Photo 11a). Flow separation that occurred on the

left bank at approximately sta 133+90 was created by the transition from a 1V:1H slope to a vertical wall (Photos 11a and 12a). A standing wave was observed at sta 133+00 near the center railroad pier (Photo 11a) and was caused by the flow separation. Flow separation also occurred on the right bank at sta 134+50 and was created by the bike trail (Photo 12a). Depth of flow along the piers tended to increase at the nose of the piers and then decrease just downstream of the nose (Plate 39, Photo 11a). This change in flow depth caused the velocities along the pier to significantly increase just downstream of the nose (Plate 40). An oblique standing wave was observed between the center and left piers at sta 131+70 (Photo 13a). The transition to return the vertical wall back to a 1V:1H slope also caused flow separation to occur on the left bank at approximately sta 125+00. Satisfactory flow conditions were observed in San Juan Creek downstream of sta 124+00.

Unbalanced discharges. The type 7 design water-surface profiles for San Juan Creek (35,000 cfs (980 cu m/sec)) and along the railroad bridge piers are shown in Plates 42 and 43, and bottom velocities are shown in Plates 44 and 45. Water-surface elevations used to plot the water-surface profiles in San Juan Creek are tabulated in Tables 9 and 10. Standing waves of approximately 2 to 3 ft (0.6 to 0.9 m) were observed downstream of the railroad bridge piers (Photo 12b), and a standing wave was observed near the center pier at sta 133+00 (Photo 11b). Flow separation occurred on the left and right banks at sta 133+90 and 134+50, respectively, and forced the flow to concentrate in the center of the channel (Photos 12b and 13b). Depth of flow along the piers increased at the nose of the piers and then decreased downstream of the nose (Plate 43, Photo 11b), which caused the velocities to significantly increase along the piers (Plate 44). Flow separation was observed on the left bank at the downstream transition near sta 125+00. Flow conditions were satisfactory downstream of the confluence beginning at sta 122+00.

Balanced discharges. Water-surface profiles for San Juan Creek (17,000 cfs (476 cu m/sec)) and along the railroad bridge piers for type 7 design are shown in Plates 46 and 47, and the water-surface elevations for the profiles are tabulated in Tables 11 and 12, respectively. Bottom velocities are shown in Plates 48 and 49. Standing waves created by the railroad bridge piers were observed downstream from the bridge (Photo 12c) and along the bridge piers (Photo 11c). Flow separation occurred on the left embankment at sta 133+90 (Photo 12c) and forced the flow toward the right bank (Photos 12c and 13c). The flow became satisfactory downstream of the confluence at approximately sta 125+00.

Scour Analysis Test (Type 7 Design)

The fixed-bed channel invert was replaced with cohesionless material, specifically fine pea-size gravel, and scour analysis experiments for the type 7 design were conducted. The scour analysis test with the 24-hr storm hydrograph and 50 percent of the peak flow for a 24-hr duration (San Juan Creek 22,000 cfs

(616 cu m/sec) and Trabuco Creek 8,000 cfs (224 cu m/sec)) was used to obtain local scour patterns associated with these events. At the conclusion of the gravel-bed experiments, it was decided, to ensure movement of the bed material, to replace the fine pea gravel with a sand and gravel mixture and rerun the 50 percent flow with 24-hr duration scour experiment. Size and weight simulation of sand in the prototype cannot be achieved in the model without introducing error due to the cohesive characteristic of silts and clays; therefore, exact reproduction of the bed material was not attempted. The material used during these experiments was to provide a quasi-stable channel and was not scaled to any prototype values.

24-hr storm hydrograph (gravel bed)

Before the gravel-bed experiment was run, the model was flooded from the upstream end. Once the model was completely saturated, the desired discharge was set. The discharges and duration of the 24-hr storm runoff hydrograph for both San Juan and Trabuco Creeks were simulated. The actual hydrographs and the simulated hydrographs for both creeks are provided in Plate 50. For the duration of the experiment, the flow remained uniform with occasional standing waves observed. The flow conditions observed around the railroad bridge piers in San Juan Creek at 1- and 2-hr intervals in the hydrograph are shown in Photos 14-33. Flow conditions observed at the confluence are shown in Photos 34-53.

At the onset of the experiment, no sediment transport was detected. It was not until 6 hr into the hydrograph (Q_{tr} 3,700 cfs (104 cu m/sec)) that sediment movement in Trabuco Creek was first noticed. In San Juan Creek, the sediment did not start moving until 14 hr into the hydrograph (Q_{sj} 38,100 cfs (1,067 cu m/sec)) (Photo 23). At 15 hr, the combined flow of San Juan and Trabuco Creek (Q_{total} 61,700 cfs (1,747 cu m/sec)) overtopped the right embankment at sta 134+00 and the left embankment downstream of the confluence at sta 126+00 (Photos 24-26 and Photos 44-46). At 17 hr, the combined flow (Q_{total} 46,700 cfs (1,308 cu m/sec)) was again contained within its banks (Photos 27 and 47). The increase in roughness from a finished concrete channel (model Manning's $n = 0.012$; prototype Manning's $n = 0.022$) to a gravel bottom channel (model Manning's $n = 0.021$; prototype Manning's $n = 0.038$) decreased the average channel velocity and increased the flow depth enough to overtop its banks. (Manning's roughness coefficients, n, were obtained from Chow[1]).

In Trabuco Creek, sediment movement was first detected just downstream of the grade control structures at sta 30+50 and 42+75. Erosion was observed along the outside curve of the channel between sta 42+00 and 32+00, and deposition was occurring along the inside curve between sta 39+00 and 34+00. Plate 51 is a contour drawing of the channel's scour patterns and scour depths for the 24-hr storm hydrograph. The scour depths shown in the drawing are not

[1] Chow, op. cit.

representative of the prototype's potential scour depths and are used only as a means to relate relative scour patterns associated with this event. At 13 hr into the hydrograph, it appeared that sediment was depositing upstream of the grade control structures. Sediment continued to move in Trabuco Creek until the end of the experiment. Localized scour patterns in Trabuco Creek were observed downstream of Del Obispo bridge piers at sta 44+00 (Photo 54), along the right bank between sta 49+00 and 44+00 (Photo 55), and between sta 34+00 and 30+00 (Photo 56), and along the left bank between sta 41+00 and 32+00 (Photos 54-56). Erosion along the sides of the channel in Trabuco Creek was presumably caused by a decrease in roughness (increase of local velocity) between the gravel bed and the concrete-lined side slopes. Deposition was observed on the right bank at sta 37+00 (Photo 55) and on the left bank at sta 30+00 (Photo 56).

In San Juan Creek, sediment movement was first noticed at the nose of the confluence. A scour hole was developed downstream of the confluence nose, and its outline is shown in Plate 51 and Photo 57. This was caused possibly by a change in flow patterns as the two creeks merged. Local scour patterns were also observed downstream of the railroad bridge piers between sta 133+00 and 130+50 and are shown in Plate 51 and Photo 58. These scour holes resembled a wake erosion shape and were caused by eddies that were generated by significant changes in the direction of flow around the bridge piers.[1] Several small scour holes were observed between sta 139+00 and 134+00 around Camino Capistrano bridge pier and are shown in Plate 51 and Photo 59.

50 percent of peak flow, 24-hr duration (gravel bed)

After the hydrograph experiment, the bed was remolded and the 50 percent peak flow with 24-hr duration was run through the model. San Juan Creek's discharge for the 50 percent peak flow was 22,000 cfs (616 cu m/sec) and Trabuco Creek's discharge was 8,000 cfs (224 cu m/sec). The flow remained stable for the duration of the experiment and was contained within its banks. No sediment movement was observed during this experiment, and no apparent scour patterns were noticeable. At the completion of this experiment, because no bed material was displaced, it was decided to replace the fine pea-size gravel with a sand and gravel mixture and rerun this experiment.

50 percent of peak flow, 24-hr duration (sand and gravel bed)

Before the 50 percent flow was set, the sand bed was dampened using a soaker hose to minimize initial scour in the model while establishing the desired

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[1] Daryl B. Simons and Fuat Senturk. (1977). *Sediment transport technology*. Water Resources Publications, Fort Collins, CO.

discharges. At the beginning of the experiment, the sediment was observed moving downstream in rolling or sliding motions at velocities slightly less than the flow. Standing waves were observed throughout the model shortly after the desired discharges were set. The height of the standing waves ranged between 6 and 9 ft (1.8 and 2.7 m) in San Juan Creek, the larger waves occurring downstream of the railroad bridge piers, and between 3 and 6 ft (0.9 and 1.8 m) in Trabuco Creek. The standing waves observed in the model appeared to be similar to standing waves associated with flow that forms antidunes in the bed material. The water and bed surface associated with antidune flow are in phase, an indication that the flow is supercritical (Froude number $F_r > 1$). The waves grow in height until they become unstable and "break like the sea surf" or they gradually subside and then subsequently reform.[1] Both of these phenomena were observed in the model. After 6 hr into the experiment (1 hr model time), the standing waves appeared to be diminishing, and the flow in the upstream portions of San Juan and Trabuco Creeks was stable. This was because an armor layer was being developed. An armor layer develops when the fine particles of the bed material are washed away, leaving behind a thin layer of coarser material (Photo 60). It was also observed that the Del Obispo bridge footings were completely exposed (Photo 61). Again, it should be noted that scour in a model such as this is qualitative only, and depths of scour in the model are not necessarily representative of depths of scour that will occur in the prototype. However, it is possible that the armoring process will develop in the prototype.

Throughout the experiment, the standing waves continued to diminish, and the flow became more stable as the armoring process moved downstream. After 24 hr, the standing waves in Trabuco Creek were observed downstream of sta 25+00 and in San Juan Creek downstream of sta 133+00. The height of the waves ranged between 1 and 2 ft (0.3 and 0.6 m) in Trabuco Creek and between 3 and 5 ft (0.9 and 1.5 m) in San Juan Creek. A contour drawing of the channel scour patterns and scour depths for this event is shown in Plate 52. The scour depths shown are not representative of the prototype's potential scour depths and are used only as a means to represent scour patterns associated with the 50 percent peak flow, 24-hr duration event. The sand dunes in Trabuco Creek (Photo 62) and the sand dunes with ripples on the back in San Juan Creek (Photo 63) are not representatives of the antidune flow described previously and were caused by a reduction in shear stress and velocity when the flow was turned off at the end of the experiment. This reduction of shear stress and velocity in the channel will probably occur in the prototype as the discharge decreases in the storm hydrograph, thus changing the bed form. It is difficult to predict bed forms because of the large number of variables that affect them; therefore, the dunes and ripples depicted in the photographs may or may not represent the prototype's bed form. There was a general degradation of the bed material in Trabuco Creek from sta 54+00 to 22+00 and in San Juan Creek from sta 150+00 to 132+00 (Plate 52, Photos 62 and 63). This was in part due to the clear water flow into the model (no suspended sediment). A buildup of sediment in Trabuco Creek at the confluence between sta 12+00 and 17+00 (Plate 52 and Photo 63)

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[1] Simons and Senturk, op.cit.

was caused by a "backwater" effect on the flow, an increase in upstream depth in Trabuco Creek caused by higher water-surface elevations in San Juan Creek. Scour along the outside curve of the channel was observed in San Juan Creek between sta 135+00 and 127+00 (Plate 52 and Photo 63) and sta 122+00 and 120+00 (Plate 52), and deposition was observed along the inside curve of the channel between sta 135+00 and 125+00 (Plate 5 and Photo 63). Armoring of the sand bed was beginning to establish along the outside curve in San Juan Creek between sta 135+00 and 127+00, as is shown in Photo 63. A scour hole was observed downstream of the confluence nose between sta 125+00 and 122+00 (Plate 52 and Photo 63) and was possibly caused by a change in flow patterns as the two creeks merged. Elongated scour patterns resembling wake erosion were observed downstream of the railroad bridge piers between sta 134+50 and 130+00 (Photo 64) and were caused by eddies generated by changes in the flow direction around the bridge piers. Scour holes along each side of the piers and between the piers were also observed (Photo 64) and possibly resulted from the pileup of water on the upstream edge and subsequent acceleration of flow around the nose of the pier. Armoring of the sand bed was beginning to take place upstream of and around the railroad bridge piers (Photo 64).

4 Conclusions and Recommendations

Conclusions

The recommended design, type 7, included the following features:

a. Widening the invert of the San Juan Channel from 150 to 192 ft (46 to 59 m) between stations 137+00 and 98+00.

b. Steepening the left embankment (east levee) on San Juan Creek from 1V:2H slope to 1V:1H slope, except between stations 132+91 and 125+97, where it transitions from the 1V:1H slope to a vertical wall.

c. Raising the left and right (west levee) embankments on San Juan Creek roughly 3 to 5 ft (0.9 to 1.5 m).

d. Removing the access road located downstream of the Camino Capistrano bridge at sta 134+00 on San Juan Creek.

e. Adding a bike trail on the left bank (east levee) at sta 134+00, near the proposed railroad bridge.

f. Removing the access road located at the confluence at sta 16+00 on Trabuco Creek.

g. Relocating the access road upstream of Del Obispo bridge from sta 46+00 to sta 49+00 on Trabuco Creek.

h. Removing the grouted rock wings.

i. Adding a debris nose on Del Obispo bridge.

j. Realigning the present railroad bridge. The proposed railroad bridge design included three debris nose bridge piers between stations 134+00

and 130+00 on San Juan Creek and concentric to the center line of the channel.

Experiments to determine the adequacy of these channel improvements for San Juan and Trabuco Creeks indicated that the proposed design (type 7) with certain modifications would effectively contain design flow conditions in the San Juan Creek channel improvement project. However, due to the magnitude of water velocities in both creeks during the design flows, protection is needed to prevent erosion of the channel beds. A paved or rock-lined channel would provide bed stability; however, the model indicated that a rock-lined channel would increase the boundary roughness and cause overtopping of the banks.

During the fixed-bed experiments, standing waves were generated by the railroad bridge piers, access roads, and bike trails. A decrease in the flow area around the railroad bridge and the change in the slope of the channel's invert at sta 134+00, as well as those of the access roads and bike trails, contributed to the generation of the standing waves observed downstream of the railroad bridge and at the confluence. The San Diego Freeway bridge piers in San Juan Creek and the grouted rock wings at the grade-control structures in Trabuco Creek generated oblique standing waves in each creek. Flow separation occurred at the access roads, bike trails, and along the left bank at the transition from a 1H:1V slope to a vertical wall and again at the transitions from the vertical wall back to the 1H:1V slope. This flow separation contributed to generation of standing waves that extended diagonally across the channel.

Three proposed designs of the railroad bridge pier were evaluated: (a) four-pier railroad bridge with debris nose (type 2 design), (b) three-pier railroad bridge with debris pier nose extensions concentric to the center line of the channel (type 6 design), and (c) three-pier railroad bridge debris nose without the pier extensions (type 7 design). In the type 2 design experiments, the flow velocity decreased between the first railroad bridge pier and the right bank and the fourth railroad bridge pier and the left bank, which caused flow to concentrate in the center of the channel between railroad bridge piers two and three (Plate 21). This caused the flow to accelerate and contributed to the generation of standing waves downstream of the railroad bridge piers. In the type 6 design experiments, a prominent standing wave that extended the width of the channel was observed at the debris nose extensions (sta 134+00) and was induced by the change in slope of the channel's invert at sta 134+00 and the decrease in flow area from the pier widths (Photo 9a). In the type 7 design experiments, a standing wave was observed near the center railroad pier (Photo 11a) caused by flow separation from the transition of the slope of the left bank from a 1V:1H slope to a vertical wall. The type 7 railroad bridge design did not adversely affect hydraulic performance.

Experiments were conducted with various training wall designs installed at the confluence: 100-ft- (30-m-) long training wall (type 3 design), 200-ft- (60-m-) long training wall (type 4 design), and 100-ft- (30-m-) long training wall positioned at a 10-degree (0.174-rad) angle with the nose of the confluence

(type 5 design). These training walls did not significantly improve hydraulic performance and caused the flow in San Juan Creek to overtop its banks.

Initial scour analysis experiments were conducted using a pea-gravel bed with the type 7 design, a 24-hr storm hydrograph, and a 50 percent peak flow for 24 hr. Because very little scour occurred with the pea-gravel bed, an experiment was conducted using a sand and gravel bed with a 50 percent peak flow for 24 hr. The material used during these experiments was not scaled to any prototype values. During the gravel-bed experiment, the flow overtopped the banks. This was caused by the increase in boundary roughness from a finished concrete channel (n = 0.022) to a gravel bottom channel (n = 0.038). The gravel-bed experiment did not show any significant scour areas. Armoring of the channel's invert is not recommended because of the significant increase in the boundary roughness. (To achieve this increase, a 1- to 2-ft- (0.3- to 0.6-m-) diam rock would be needed to armor the invert.)

At the beginning of the scour analysis experiment using the sand and gravel bed, the sediment was observed moving downstream in rolling or sliding motions at velocities slightly less than the flow. Standing waves were observed throughout the model and appeared to be similar to standing waves associated with flow that forms antidunes in the bed material. After 6 hr into the experiment (1 hr model time), the standing waves appeared to be diminishing and the flow upstream was stable. This was because an armor layer was being developed. The scour analysis experiment for the sand and gravel bed revealed a general degradation of the bed material in both San Juan and Trabuco Creeks. However, a buildup of sediment was observed in Trabuco Creek at the confluence (Plate 52 and Photo 63) and was caused by a "backwater" effect on the flow. Scour along the outside curve of the channel was observed in San Juan Creek as well as deposition along the inside curve of the channel. Armoring of the sand bed was beginning to establish upstream of and around the railroad bridge piers and along the outside curve of the channel in San Juan Creek. Elongated scour patterns resembling wake erosion were observed downstream of the railroad bridge piers and were caused by eddies generated by changes in the flow direction around the bridge piers. Scour holes along each side of the piers and between the piers were also observed and were resulting from the pileup of water on the upstream edge and subsequent acceleration of flow around the nose of the pier. The scour analysis experiments conducted are qualitative assessments of the channel's potential scour problems.

Recommendations

The standing waves observed during the fixed-bed experiments were indicative of an unstable environment. In supercritical flow, any abrupt changes in the channel configuration, such as an access road, bike trail, decrease in flow area, or a significant change in the channel's invert slope, will generate standing

waves. As long as these standing waves are not in and around a hydraulic structure, such as a bridge, they do not adversely affect the hydraulic performance of the fixed-bed channel. However, if the standing waves impact the bottom of a bridge, the bridge can become "pressurized" and cause the water depth to increase, creating a backwater effect. During the fixed-bed experiments, the standing waves observed downstream of the railroad bridge on San Juan Creek did not adversely affect the hydraulic performance of the channel, nor did the standing waves generated by the access roads, located upstream of the Del Obispo bridge on Trabuco Creek and upstream of the railroad bridge on San Juan Creek (type 2 design), impact the bridges downstream of these roads. However, it is recommended that the access roads be relocated downstream of the Del Obispo bridge on Trabuco Creek and downstream of the railroad bridge on San Juan Creek. To reduce the magnitude of the standing waves that occur downstream of the railroad bridge, it is also recommended that the channel's invert slope be reshaped to create a gradual transition between stations 145+00 and 130+00. To eliminate the standing waves downstream of the grade control stabilizers in Trabuco Creek, it is recommended that the grouted rock wings be removed. During the experiments, the model showed that the flow overtopped the banks around the San Diego Freeway. This was not documented in this report because it is believed to be model related and will not occur in the prototype. However, to increase the flow area through the bridge piers, it is recommended that the grouted rock side slopes in this vicinity also be removed.

Water depths measured during the fixed-bed experiments were average depths of the water fluctuations. It is recommended to add 1 ft (0.3 m) to the water-surface elevations to obtain an approximation of the maximum water depth. This new water-surface elevation can be used with the OCFC's freeboard criteria to determine levee heights.

The standing waves observed at the beginning of the scour analysis experiment using the sand and gravel bed were also indicative of an unstable environment. The magnitude of the bottom velocities measured during the fixed-bed experiments and the large areas of potential scour problems determined from the scour analysis experiments reveal that the channel cannot handle the design flows without possible failure and protection is needed to provide bed stability. Therefore, it is strongly recommended that the entire channel invert be paved with concrete. This is to include the model study area between stations 150+00 and 98+00 on San Juan Creek and sta 51+00 to the confluence on Trabuco Creek. The channel invert paving should be extended downstream of the study area to a point where the channel becomes stable.

In summary, the modifications required to provide adequate protection during the design flow consist of (a) paving the channel's invert and side slopes with concrete to eliminate scour in both channels, (b) reshaping the channel's invert slope to create a gradual transition between stations 145+00 and 130+00 to reduce the magnitude of the standing waves, (c) relocating the access roads downstream of all bridges to prevent possible bridge pressurization, and

(d) removing the grouted rock wings on Trabuco and San Juan Creeks to reduce the magnitude of the oblique standing waves.

Table 1
Water-Surface Elevations, Type 1 Design, Q_{sj} 42,000 cfs (1,176 cu m/sec), Q_{tr} 17,000 cfs (476 cu m/sec)

Station	Invert	Top of Slope	Left Bank	Center Line	Right Bank
San Juan Creek					
149+53	66.53	79.32	80.6	81.5	82.3
149+00	66.32	79.12	81.0	80.9	82.9
148+00	65.92	78.72	80.6	76.9	82.3
147+00	65.52	78.32	80.6	79.3	80.5
146+00	65.12	77.92	79.8	79.4	79.0
145+00	64.72	77.52	80.5	74.4	74.9
144+00	63.71	77.39	79.0	72.3	77.2
143+00	62.71	77.27	78.7	71.7	72.2
142+00	62.01	77.01	71.4	71.6	71.9
141+00	61.55	77.70	73.6	73.5	72.3
140+00	61.12	76.00	74.5	74.8	73.5
139+00	60.72	75.72	74.1	72.3	73.6
138+00	60.25	75.25	72.1	72.6	73.2
137+00	59.82	74.82	73.1	74.3	74.1
136+00	59.56	74.56	70.7	72.9	73.9
135+00	59.36	74.36	71.1	70.0	71.3
134+00	58.96	73.96	72.4	72.0	72.3
133+00	58.56	73.56	71.7	71.9	72.8
132+00	58.16	73.16	71.8	71.8	73.4
131+00	57.76	72.76	72.9	73.2	73.6
130+00	57.36	72.36	71.8	72.8	72.6
129+00	56.96	71.96	74.8	72.9	70.5
128+00	56.56	71.56	74.7	69.6	66.9
127+00	56.12	71.60	61.3	68.0	69.3
126+00	55.50	72.0	65.8	66.5	66.0
125+00	54.91	71.41	67.2	64.2	66.4
124+00	54.32	70.82	67.5	65.0	62.3
123+00	53.73	70.23	66.7	65.2	64.7
122+00	53.14	69.64	64.3	64.0	63.3

(Sheet 1 of 3)

Table 1 (Continued)

Station	Invert	Top of Slope	Left Bank	Center Line	Right Bank
121+00	52.55	69.05	64.4	63.7	62.4
120+00	51.95	68.45	63.9	62.3	61.0
119+00	51.35	67.85	64.1	61.5	60.1
118+00	50.78	67.28	63.5	61.8	59.5
117+00	50.18	66.68	61.6	60.5	59.9
116+00	49.58	66.08	61.0	60.4	59.2
115+00	49.14	65.64	62.4	60.3	57.9
114+00	48.70	65.20	62.0	60.3	58.8
113+00	48.82	64.76	61.1	60.2	58.7
112+00	47.82	64.32	62.0	59.6	59.0
111+00	47.38	63.88	60.6	59.5	59.4
110+00	46.94	63.44	51.4	58.1	58.3
109+00	46.50	63.00	57.8	57.9	58.9
108+00	46.06	62.56	57.5	57.0	57.9
107+00	45.62	62.12	57.6	56.5	56.2
106+00	45.18	61.68	57.6	56.4	56.2
105+00	44.74	61.24	60.8	57.0	62.7
			Trabuco Creek		
51+00	78.81	92.81	89.4	89.1	89.5
50+00	76.86	90.86	84.3	86.1	84.7
49+00	76.36	90.36	84.1	85.8	84.2
48+00	75.86	89.86	84.5	84.2	84.4
47+00	75.36	89.36	83.1	83.2	83.0
46+00	74.86	90.15	83.9	83.5	83.4
45+11	74.41	90.41	81.7	82.3	85.3
44+40	74.06	90.06	82.3	82.5	83.0
44+00	73.86	87.86	83.3	83.3	82.0
43+00	73.36	87.36	79.0	79.0	79.6
42+54	71.24	85.24	78.6	80.7	77.0
42+00	70.96	84.96	80.2	78.2	79.3
41+00	70.44	84.44	76.4	75.5	74.6
40+00	69.93	83.93	77.7	78.4	78.1

(Sheet 2 of 3)

Table 1 (Concluded)

Station	Invert	Top of Slope	Left Bank	Center Line	Right Bank
39+00	69.41	83.41	78.7	78.7	77.1
38+00	68.89	82.89	79.2	77.1	77.3
37+00	68.37	82.37	78.3	76.8	77.8
36+00	67.85	81.85	77.8	75.9	76.5
35+00	67.33	81.33	74.7	76.0	77.1
34+00	66.81	80.81	74.7	74.5	75.7
33+00	66.29	80.29	75.1	74.8	74.8
32+00	65.78	79.78	74.4	74.3	74.1
31+00	65.26	79.26	73.1	73.8	73.5
30+45	63.07	77.07	73.6	72.7	74.4
30+08	62.90	76.90	69.2	71.3	68.7
29+00	62.40	76.40	70.6	71.1	70.4
28+00	61.95	75.95	70.8	69.3	70.5
27+00	61.49	75.49	69.8	69.3	68.8
26+00	61.04	75.04	68.7	68.7	69.9
25+00	60.58	74.58	69.4	68.8	68.9
24+00	60.12	74.12	68.1	68.5	68.7
23+00	59.67	73.67	67.8	67.6	68.1
22+00	59.21	73.21	68.1	67.8	68.1
21+00	58.76	72.76	67.6	66.7	68.1
19+00	57.84	71.84	72.0	69.2	67.3
17+71	57.07	71.07	71.8	70.9	67.0
16+51	56.35	71.60	69.8	69.0	69.0
15+18	55.50	72.00	65.8	66.5	66.0
14+31	54.91	71.41	67.2	64.2	66.9

(Sheet 3 of 3)

Table 2
Water-Surface Elevations, Type 1 Design, Q_{sj} 35,000 cfs (980 cu m/sec), Q_{tr} 5,000 cfs (140 cu m/sec)

Station	Invert	Top of Slope	Left Bank	Center Line	Right Bank
San Juan Creek					
149+54	66.54	79.32	79.5	80.4	80.8
149+00	66.32	79.12	80.4	80.2	81.6
148+00	65.92	78.72	79.9	80.0	81.3
147+00	65.52	78.32	79.8	79.2	79.8
146+00	65.12	77.92	78.0	78.8	76.8
145+00	64.72	77.52	78.5	72.9	73.6
144+00	63.71	77.39	78.3	72.5	71.3
143+00	62.71	77.27	74.2	70.8	71.0
142+00	62.01	77.01	70.5	70.9	70.1
141+00	61.55	77.70	71.5	70.4	70.6
140+00	61.12	76.00	73.8	67.0	72.0
139+00	60.72	75.72	73.6	73.0	72.0
138+00	60.25	75.25	70.5	70.4	71.4
137+00	59.82	74.82	70.9	71.6	72.2
136+00	59.56	74.56	69.8	71.3	72.3
135+00	59.36	74.36	70.6	70.0	70.4
134+00	58.96	73.96	71.4	72.4	71.2
133+00	58.56	73.56	70.9	70.2	72.1
132+00	58.16	73.16	71.0	72.9	72.2
131+00	57.76	72.76	71.4	71.5	72.3
130+00	57.36	72.36	71.3	69.6	71.9
129+00	56.96	71.96	73.2	70.4	70.5
128+00	56.56	71.56	72.6	69.4	67.6
127+00	56.12	71.60	60.6	67.0	65.4
126+00	55.50	72.0	63.2	62.2	65.0
125+00	54.91	71.41	61.5	62.4	64.0
124+00	54.32	70.82	61.4	63.1	62.2
123+00	53.73	70.23	63.1	61.1	59.2
122+00	53.14	69.64	62.3	60.9	59.1

(Sheet 1 of 3)

Table 2 (Continued)					
Station	Invert	Top of Slope	Left Bank	Center Line	Right Bank
121+00	52.55	69.05	60.8	60.5	59.0
120+00	51.95	68.45	60.5	59.6	59.6
119+00	51.35	67.85	59.7	58.5	58.1
118+00	50.78	67.28	61.0	58.5	56.9
117+00	50.18	66.68	59.2	58.4	57.6
116+00	49.58	66.08	57.8	57.6	56.6
115+00	49.14	65.64	59.6	57.3	56.4
114+00	48.70	65.20	57.9	57.8	56.4
113+00	48.82	64.76	57.9	58.0	56.2
112+00	47.82	64.32	59.1	57.6	56.6
111+00	47.38	63.88	57.6	56.7	56.5
110+00	46.94	63.44	56.1	56.2	55.6
109+00	46.50	63.00	54.7	56.0	55.6
108+00	46.06	62.56	54.6	55.1	55.2
107+00	45.62	62.12	54.3	53.9	54.0
106+00	45.18	61.68	54.3	53.6	53.3
105+00	44.74	61.24	53.2	54.5	55.2
Trabuco Creek					
51+00	78.81	92.81	83.5	83.8	83.8
50+00	76.86	90.86	80.5	81.0	80.9
49+00	76.36	90.36	79.6	80.2	79.8
48+00	75.86	89.86	79.9	80.3	79.8
47+00	75.36	89.36	79.3	79.5	79.0
46+00	74.86	88.86	79.2	78.9	78.9
45+07	74.39	88.39	79.2	80.2	79.7
44+00	73.86	87.86	78.3	77.7	77.5
43+00	73.36	87.36	77.1	44.1	77.7
42+75	73.24	87.24			73.7
42+55	71.24	85.24	74.3		72.0
42+00	70.96	84.96	75.5	73.6	74.7
41+41	70.64	84.64		75.4	
41+00	70.44	84.44	73.9	74.0	74.7

Table 2 (Concluded)

Station	Invert	Top of Slope	Left Bank	Center Line	Right Bank
40+00	69.93	83.93	74.4	74.1	73.4
39+00	69.41	83.41	73.8	73.9	73.8
38+00	68.89	82.89	73.8	73.5	73.5
37+00	68.37	82.37	72.2	72.3	72.6
36+00	67.85	81.85	71.8	71.6	71.8
35+00	67.33	81.33	71.3	71.4	71.4
34+00	66.81	80.81	70.9	70.8	71.0
33+00	66.29	80.29	70.4	70.4	70.1
32+00	65.78	79.78	70.0	69.8	70.2
31+00	65.26	79.26	69.0	69.2	69.1
30+50	65.0	79.0	69.4		69.7
30+30	63.0	77.0	65.6		65.3
29+00	62.40	76.40	65.6	65.8	66.0
28+00	61.95	75.95	65.5	65.9	65.8
27+00	61.49	75.49	65.2	65.2	65.3
26+00	61.04	75.04	64.9	65.2	65.4
25+00	60.58	74.58	65.0	64.8	65.0
24+00	60.12	74.12	64.8	64.9	64.8
23+00	59.67	73.67	63.8	63.7	63.9
22+00	59.21	73.21	64.7	64.8	64.8
21+00	58.76	72.76	64.8	64.8	65.0
19+00	57.84	71.84	66.5	65.0	65.8
17+71	57.07	71.07	66.9	65.4	63.6
16+51	56.35	71.60	65.5	65.6	65.4
15+18	55.50	72.00	63.2	62.2	65.0
14+31	54.91	71.41	61.5	62.4	64.0

Table 3
Water-Surface Elevations, Type 1 Design, Q_{sj} 17,000 cfs (476 cu m/sec) Q_{tr} 17,000 cfs (476 cu m/sec)

Station	Invert	Top of Slope	Left Bank	Center Line	Right Bank
San Juan Creek					
149+36	66.46	79.26	74.9	75.4	75.9
149+00	66.32	79.12	75.7	75.0	76.2
148+00	65.92	78.72	75.3	76.0	76.2
147+00	65.52	78.32	75.1	74.3	74.0
146+00	65.12	77.92	72.6	73.5	70.9
145+00	64.72	77.52	73.6	70.0	70.7
144+00	63.71	77.39	73.2	69.6	69.0
143+00	62.71	77.27	70.1	68.2	68.6
142+00	62.01	77.01	67.7	67.6	67.2
141+00	61.55	77.70	68.0	67.3	67.1
140+00	61.12	76.00	69.1	68.5	68.1
139+00	60.72	75.72	69.2	67.7	66.7
138+00	60.25	75.25	66.8	66.5	67.4
137+00	59.82	74.82	66.7	66.9	67.8
136+00	59.56	74.56	66.9	67.6	68.0
135+00	59.36	74.36	66.8	66.5	67.3
134+00	58.96	73.96	67.3	67.1	67.6
133+00	58.56	73.56	66.4	66.7	67.4
132+00	58.16	73.16	67.0	68.8	67.9
131+00	57.76	72.76	67.2	69.0	67.6
130+00	57.36	72.36	65.0	66.4	67.4
129+00	56.96	71.96	69.2	66.8	64.5
128+00	56.56	71.56	68.2	65.0	62.8
127+00	56.12	71.60	60.9	63.5	63.6
126+42	55.76	72.25	62.2	62.2	64.0
126+00	55.50	72.0	62.7	63.4	62.7
125+00	54.91	71.41	63.7	61.6	62.6
124+00	54.32	70.82	63.0	62.3	61.2
123+00	53.73	70.23	62.7	61.6	58.9

Table 3 (Continued)

Station	Invert	Top of Slope	Left Bank	Center Line	Right Bank
122+00	53.14	69.64	61.4	61.6	60.0
121+00	52.55	69.05	60.4	60.2	59.1
120+00	51.95	68.45	58.0	59.5	60.9
119+00	51.35	67.85	60.5	58.7	57.4
118+00	50.78	67.28	60.2	58.7	56.3
117+00	50.18	66.68	58.3	57.3	57.1
116+00	49.58	66.08	57.1	57.4	56.3
115+00	49.14	65.64	58.5	56.8	55.8
114+00	48.70	65.20	57.6	57.1	55.9
113+00	48.82	64.76	57.3	57.9	55.7
112+00	47.82	64.32	58.7	57.0	56.0
111+00	47.38	63.88	56.1	56.3	55.9
110+00	46.94	63.44	55.3	55.4	55.4
109+00	46.50	63.00	54.2	54.5	54.9
108+00	46.06	62.56	54.0	54.2	54.1
107+00	45.62	62.12	53.9	53.3	53.5
106+00	45.18	61.68	52.7	53.3	53.3
Trabuco Creek					
50+00	76.86	90.86	85.6	86.4	84.2
49+00	76.36	90.36	84.6	85.4	84.5
48+00	75.86	89.86	84.2	84.6	84.9
47+00	75.36	89.36	84.4	83.8	83.8
46+00	74.86	88.86	83.8	83.7	83.5
45+00	74.36	88.36	81.7	82.5	81.7
44+00	73.86	87.86	82.7	82.9	81.7
43+00	73.36	87.36	82.1	82.3	82.8
42+75	73.24	87.24	81.9	81.9	83.3
42+55	71.24	85.24	78.9	81.2	77.2
42+00	70.96	84.86	80.1	79.2	77.9
41+00	70.44	84.44	77.7	78.1	77.7
40+00	69.93	83.93	78.7	78.7	77.2
39+00	69.41	83.41	79.0	77.5	77.4

(Sheet 2 of 3)

Table 3 (Concluded)					
Station	Invert	Top of Slope	Left Bank	Center Line	Right Bank
38+00	68.89	82.89	78.1	76.6	77.9
37+00	68.37	82.37	78.0	76.1	76.5
36+00	67.85	81.85	74.8	76.2	77.3
35+00	67.33	81.33	76.4	75.3	75.3
34+00	66.81	80.81	75.0	74.8	76.0
33+00	66.29	80.29	75.2	74.8	74.8
32+00	65.78	79.78	74.6	74.4	74.3
31+00	65.26	79.26	73.1	73.9	73.5
30+50	65.0	79.0	73.9	73.3	74.7
30+30	63.0	77.0	68.9	71.5	68.1
29+00	62.40	76.40	70.6	71.4	70.6
28+00	61.95	75.95	70.7	69.4	70.8
27+00	61.49	75.49	69.6	69.5	68.7
26+00	61.04	75.04	69.1	68.7	69.9
25+00	60.58	74.58	69.5	68.9	69.0
24+00	60.12	74.12	68.6	68.7	68.8
23+00	59.67	73.67	67.8	67.8	68.2
22+00	59.21	73.21	68.07	68.1	68.2
21+00	58.76	72.76	67.6	67.1	67.9
19+00	57.84	71.84	68.6	66.5	65.2
17+71	57.07	71.07	64.4	67.6	64.6
16+51	56.35	70.35	64.3	64.4	64.4
15+94	56.37	70.37	64.4	62.4	63.2
15+18	55.50	69.50	62.7	63.4	62.7
14+31	54.91	68.91	63.7	61.6	62.6
					(Sheet 3 of 3)

Table 4
Water-Surface Elevations, Type 2 Design, Q_{sj} 42,000 cfs (1,176 cu m/sec), Q_{tr} 17,000 cfs (476 cu m/sec)

Station	Invert	Top of Slope	Left Bank	Center Line	Right Bank
San Juan Creek					
149+53	66.53	79.33	80.6	81.5	82.3
149+00	66.32	79.12	81.0	80.9	82.9
148+00	65.92	78.72	80.6	76.9	82.3
147+00	65.52	78.32	80.6	79.3	80.5
146+00	65.12	77.92	79.8	79.4	79.0
145+00	64.72	77.52	80.5	74.4	74.9
144+00	63.71	77.39	79.0	72.3	77.2
143+00	62.71	77.27	78.7	71.7	72.2
142+00	62.01	77.01	72.4	73.0	72.2
140+00	61.12	76.0	74.4	75.4	73.9
138+00	60.25	75.25	71.2	71.4	71.6
137+00	58.46	73.46	68.9	68.5	70.2
136+00	57.10	77.10	65.9	67.5	68.3
135.00	56.55	76.55	66.7	65.5	67.6
134+00	56.0	76.0	67.5	73.1	68.3
133+00	55.65	75.65	67.9	71.8	70.3
132+00	55.30	75.30	68.4	67.1	65.2
131+00	54.95	74.95	68.3	63.1	66.7
129+00	54.25	74.25	66.7	66.8	68.7
128+00	53.90	73.90	67.4	64.8	67.3
127+00	53.70	73.70	68.1	68.1	67.1
126+00	53.50	73.50	68.3	72.1	68.4
125+00	53.31	73.31	68.4	66.5	68.8
124+00	53.11	73.11	61.2	68.3	67.2
122+00	52.72	72.72	67.2	67.5	67.3
120+00	51.99	71.99	64.1	63.9	63.4
118+00	50.93	70.93	62.0	62.6	61.8
116+00	49.86	67.89	62.6	61.5	60.8
114+00	48.70	65.20	62.2	61.2	59.4
112+00	47.82	64.32	63.1	60.9	59.5

(Continued)

Table 4 (Concluded)

Station	Invert	Top of Slope	Left Bank	Center Line	Right Bank
111+00	47.38	63.88	60.6	59.5	59.4
110+00	46.94	63.44	51.4	58.1	58.3
109+00	46.50	63.0	57.8	57.9	58.9
108+00	46.06	62.56	57.5	57.0	57.9
107+00	45.62	62.12	57.6	56.5	56.2
106+00	45.18	61.68	57.6	56.4	56.2
105+00	44.74	61.24	60.8	57.0	62.7
Trabuco Creek					
51+00	78.81	92.81	89.4	89.1	89.5
50+00	76.86	90.86	84.3	86.1	84.7
49+00	76.36	90.36	84.1	85.8	84.2
48+00	75.86	89.86	85.0	84.8	84.0
47+00	75.36	89.36	83.5	82.6	82.1
46+00	74.86	88.86	83.8	84.3	84.7
45+00	74.36	88.36	84.0	82.8	83.1
44+00	73.86	87.86	83.9	83.7	81.8
43+00	73.36	87.36	81.7	82.2	83.6
42+55	71.24	85.24	78.9	79.6	77.5
42+00	70.96	84.96	80.7	78.5	79.3
40+00	69.93	83.93	78.7	78.7	77.1
38+00	68.89	82.89	78.3	76.8	77.8
36+00	67.85	81.85	74.7	76.0	77.1
34+00	66.81	80.81	74.7	74.5	75.7
32+00	65.78	79.78	74.4	74.3	74.1
30+08	62.86	76.86	69.2	71.3	68.7
28+00	61.95	75.95	70.8	69.3	70.5
26+00	61.04	75.04	68.7	68.7	69.9
22+00	59.21	73.21	68.1	67.8	68.1
19+00	57.84	71.84	72.0	69.2	67.3
17+71	57.07	71.07	67.6	65.9	65.9
16+51	56.35	72.0	68.5	67.0	67.2
15+18	53.50	73.50	65.8	66.5	66.0

Table 5
Water-Surface Elevations, Type 2 Design, Q_{sj} 35,000 cfs (980 cu m/sec), Q_{tr} 5,000 cfs (140 cu m/sec)

Station	Invert	Top of Slope	Left Bank	Center Line	Right Bank
San Juan Creek					
149+54	66.53	79.33	79.5	80.4	80.8
149+00	66.32	79.12	80.4	80.2	81.6
148+00	65.92	78.72	79.9	80.0	81.3
147+00	65.52	78.32	79.8	79.2	79.8
146+00	65.12	77.92	78.0	78.8	76.8
145+00	64.72	77.52	78.5	72.9	73.6
144+00	63.71	77.39	78.3	72.5	71.3
143+00	62.71	77.27	74.2	70.8	71.0
142+00	62.01	77.01	70.5	70.9	70.1
141+00	61.55	77.70	71.5	70.4	70.6
140+00	61.12	76.0	73.8	67.0	72.0
139+00	60.72	75.72	73.6	73.0	72.0
138+00	60.25	75.25	70.0	70.0	70.6
137+00	58.46	73.46	67.0	67.5	68.3
136+00	57.10	77.10	66.8	65.7	64.2
135+00	56.55	76.55	65.9	64.3	67.4
134+00	56.0	76.0	66.1	66.1	68.6
133+00	55.65	75.65	66.2	66.5	68.8
132+00	55.30	75.30	67.3	64.2	63.3
131+00	54.95	74.95	66.7	62.9	66.7
130+00	54.60	74.60	65.4	64.2	67.5
129+00	54.25	74.25	63.0	66.3	66.6
128+00	53.90	73.90	63.4	62.8	63.2
127+00	53.70	73.70	62.5	63.5	63.5
126+00	53.50	73.50	62.6	63.2	63.7
125+00	53.31	73.31	64.2	63.8	63.9
124+00	53.11	73.11	61.4	63.1	62.2
123+00	52.91	72.91	63.1	61.1	59.2
122+00	52.72	72.72	62.3	60.9	59.1
121+00	52.52	72.52	60.8	60.5	59.0

(Sheet 1 of 3)

Table 5 (Continued)

Station	Invert	Top of Slope	Left Bank	Center Line	Right Bank
120+00	51.99	71.99	60.5	59.6	59.6
119+00	51.43	71.43	59.7	58.5	58.1
118+00	50.93	70.93	61.0	58.5	56.9
117+00	50.39	70.40	59.2	58.4	57.6
116+00	49.86	67.89	57.8	57.6	56.6
115+00	49.33	65.38	59.6	57.3	56.4
114+00	48.70	65.20	57.9	57.8	56.4
113+00	48.26	64.76	57.9	58.0	56.2
112+00	47.82	64.32	59.1	57.6	56.6
111+00	47.38	63.88	57.6	56.7	56.5
110+00	46.94	63.44	56.1	56.2	55.6
109+00	46.50	63.0	54.7	56.0	55.6
108+00	46.06	62.56	54.6	55.1	55.2
107+00	45.62	62.12	54.3	53.9	54.0
106+00	45.18	61.68	54.3	53.6	53.3
105+00	44.74	61.24	53.2	54.5	55.2
		Trabuco Creek			
51+00	78.81	92.81	83.5	83.8	83.8
50+00	76.86	90.86	80.5	81.0	80.9
49+00	76.36	90.36	81.1	81.2	81.1
48+00	75.86	89.86	80.8	81.0	80.4
47+00	75.36	89.36	79.8	79.4	79.3
46+00	74.86	88.86	80.3	80.3	80.7
45+00	74.36	88.36	79.8	79.8	79.5
44+00	73.86	87.86	78.9	78.6	78.1
43+00	73.36	87.36	78.0	78.5	78.2
42+55	71.24	85.24	74.6	75.6	74.7
42+00	70.96	84.96	75.7	74.1	74.4
40+00	69.93	83.93	74.4	74.1	73.4
38+00	68.89	82.89	73.8	73.5	73.5
36+00	67.85	81.85	71.8	71.6	71.8
34+00	66.81	80.81	70.9	70.8	71.0

(Sheet 2 of 3)

Table 5 (Concluded)

Station	Invert	Top of Slope	Left Bank	Center Line	Right Bank
32+00	65.78	79.78	70.0	69.8	70.2
30+50	65.0	79.0	69.4		69.7
28+00	61.95	75.95	65.6	65.8	66.0
26+00	61.04	75.04	64.9	65.2	65.4
24+00	60.12	74.12	64.8	64.9	64.8
22+00	59.21	73.21	64.7	64.8	64.8
19+00	57.84	71.84	62.3	62.3	61.7
17+71	57.07	71.07	63.1	62.0	62.1
16+51	56.35	72.0	63.3	63.3	63.1

(Sheet 3 of 3)

Table 6
Water-Surface Elevations, Type 2 Design, Q_{sj} 17,000 cfs (476 cu m/sec) Q_{tr} 17,000 cfs (476 cu m/sec)

Station	Invert	Top of Slope	Left Bank	Center Line	Right Bank
San Juan Creek					
149+36	66.53	79.33	74.9	75.4	75.9
149+00	66.32	79.12	75.7	75.0	76.2
148+00	65.92	78.72	75.3	76.0	76.2
147+00	65.52	78.32	75.1	74.3	74.0
146+00	65.12	77.92	72.6	73.5	70.9
145+00	64.72	77.52	73.6	70.0	70.7
144+00	63.71	77.39	73.2	69.6	69.0
143+00	62.71	77.27	70.1	68.2	68.6
142+00	62.01	77.01	67.7	67.6	67.2
141+00	61.55	77.70	68.0	67.3	67.1
140+00	61.12	76.0	69.1	68.5	68.1
139+00	60.72	75.72	69.2	67.7	66.7
138+00	60.25	75.25	66.9	66.1	67.0
137+00	58.46	73.46	64.1	64.1	64.7
136+00	57.10	77.10	61.2	61.6	64.2
135+00	56.55	76.55	63.3	63.8	64.1
134+00	56.0	76.0	62.6	63.3	64.2
133+00	55.65	75.65	63.1	61.7	62.5
132+00	55.30	75.30	63.4	61.6	61.7
131+00	54.95	74.95	63.3	62.9	63.6
130+00	54.60	74.60	63.2	63.8	64.1
129+00	54.25	74.25	64.0	64.2	61.8
128+00	53.90	73.90	63.4	63.3	63.9
127+00	53.70	73.70	63.6	65.0	64.4
126+00	53.50	73.50	63.7	63.9	63.8
125+00	53.31	73.31	63.6	63.4	60.7
124+00	53.11	73.11	63.4	63.4	63.0
123+00	52.91	72.91	62.7	61.6	58.9
122+00	52.72	72.72	61.4	61.6	60.0

(Sheet 1 of 3)

Table 6 (Continued)

Station	Invert	Top of Slope	Left Bank	Center Line	Right Bank
121+00	52.52	72.52	60.4	60.2	59.1
120+00	51.99	71.99	58.0	59.5	60.9
119+00	51.43	71.43	60.5	58.7	57.4
118+00	50.93	70.93	60.2	58.7	56.3
117+00	50.39	70.40	58.3	57.3	57.1
116+00	49.86	67.89	57.1	57.4	56.3
115+00	49.33	65.38	58.5	56.8	55.8
114+00	48.70	65.20	57.6	57.1	55.9
113+00	48.26	64.76	57.3	57.9	55.7
112+00	47.82	64.32	58.7	57.0	56.0
111+00	47.38	63.88	56.1	56.3	55.9
110+00	46.94	63.44	55.3	55.4	55.4
109+00	46.50	63.00	54.2	54.2	54.9
108+00	46.06	62.56	54.0	54.2	54.1
107+00	45.62	62.12	53.9	53.3	53.5
106+00	45.18	61.68	52.7	53.3	53.3
		Trabuco Creek			
50+00	76.86	90.86	85.6	86.4	84.2
49+00	76.36	90.36	84.6	85.4	84.5
48+00	75.86	89.86	85.0	84.6	82.9
47+00	75.36	89.36	83.9	82.9	84.1
46+00	74.86	88.86	84.1	85.2	84.7
45+00	74.36	88.36	83.8	83.0	83.1
44+00	73.86	87.86	83.9	83.8	82.1
43+00	73.36	87.36	81.8	82.6	83.3
42+55	71.24	85.24	79.3	79.6	77.3
42+00	70.96	84.96	80.6	78.5	79.2
40+00	69.93	83.93	78.7	78.7	77.2
38+00	68.89	82.89	78.1	76.6	77.9
36+00	67.85	81.85	74.8	76.2	77.3
34+00	66.81	80.81	75.0	74.8	76.0
32+00	65.78	79.78	74.6	74.4	74.3

(Sheet 2 of 3)

Table 6 (Concluded)

Stations	Invert	Top of Slope	Left Bank	Center Line	Right Bank
30+50	65.0	79.00	73.9	73.3	74.7
28+00	61.95	75.95	70.7	69.4	70.8
26+00	61.04	75.04	69.1	68.7	69.9
24+00	60.12	74.12	68.6	68.7	68.8
22+00	59.21	73.21	68.1	68.1	68.2
19+00	57.84	71.84	68.6	66.5	65.2
17+71	57.07	71.07	65.5	65.8	66.2
16+51	56.35	72.00	64.8	64.3	64.9
14+31	53.31	73.31	63.7	61.6	62.6

(Sheet 3 of 3)

Table 7
Water-Surface Elevations, Type 7 Design, San Juan Creek, Q_{sj} 42,000 cfs (1,176 cu m/sec), Q_{tr} 17,000 cfs (476 cu m/sec)

Station	Invert	Top of Slope	Left Bank	Center Line	Right Bank
149+53	66.53	79.33	80.6	81.5	82.3
149+00	66.32	79.12	81.0	80.9	82.9
148+00	65.92	78.72	80.6	76.9	82.3
147+00	65.52	78.32	80.6	79.3	80.5
146+00	65.12	77.92	79.8	79.4	79.0
145+00	64.72	77.52	80.5	74.4	74.9
144+00	63.71	77.39	79.0	72.3	77.2
143+00	62.71	77.27	78.7	71.7	72.2
142+00	62.01	77.01	72.4	73.0	72.2
140+00	61.12	76.00	74.4	75.4	73.9
138+00	60.25	75.25	71.2	71.4	71.6
137+00	58.46	73.46	70.5	69.3	72.9
136+00	57.64	77.64	67.9	68.7	70.2
135+00	56.82	76.82	66.9	66.0	69.3
134+00	56.00	76.00	64.4	66.1	69.2
133+00	55.65	75.65	68.7	70.4	71.7
132+00	55.30	75.30	69.3	67.2	69.2
131+00	54.95	74.95	65.0	63.9	71.4
130+00	54.60	74.60	74.4	73.5	73.2
129+00	54.25	74.25	74.3	75.9	76.8
128+00	53.90	73.90	68.1	69.4	70.5
127+00	53.70	73.70	60.2	60.3	61.8
126+00	53.51	73.51	69.5	71.0	71.8
125+00	53.31	73.31	69.3	68.1	70.2
124+00	53.11	73.11	70.1	69.6	70.0
123+00	52.91	72.91	69.5	68.1	70.6
122+00	52.72	72.72	69.5	68.6	69.9
121+00	52.52	72.52	68.8	66.9	68.8
120+00	51.99	71.99	67.4	66.9	66.7
119+00	51.46	71.46	67.2	64.3	64.1
118+00	50.93	70.93	66.2	62.6	62.3

(Continued)

Table 7 (Concluded)					
Station	Invert	Top of Slope	Left Bank	Center Line	Right Bank
117+00	50.39	70.39	66.1	62.4	64.7
116+50	50.16	68.19	65.5	66.2	64.6
116+00	49.86	67.89	65.5	62.8	64.6
115+00	49.33	65.38	64.4	61.4	61.6
114+00	48.70	65.20	63.9	61.5	61.9
113+00	48.26	64.76	63.4	62.9	61.9
112+00	47.82	64.32	63.1	61.9	61.4
111+00	47.38	63.88	61.1	59.7	60.7
110+00	46.94	63.44	60.5	58.3	60.1
109+00	46.50	63.00	59.0	58.6	59.5
108+00	46.06	62.56	59.2	57.2	59.2
107+00	45.62	62.12	57.6	56.9	57.9
106+00	45.18	61.68	58.5	56.0	58.5
105+00	44.74	61.24	57.1	57.0	58.6

Table 8
Water-Surface Elevations, Type 7 Design, Proposed Railroad Bridge, San Juan Creek, Q_{sj} 42,000 cfs (1,176 cu m/sec), Q_{tr} 17,000 cfs (476 cu m/sec)

Station	Left Side of Pier	Right Side of Pier
	North Pier	
134+17	65.8	
133+95	69.3	69.6
133+74	65.6	
133+65		65.1
133+41	65.8	66.6
133+07	65.9	67.8
133+06	65.6	
	Center Pier	
133+30	67.8	
132+99		71.2
132+90	73.0	
132+78		64.2
132+53		66.5
132+33	65.1	
132+11	69.2	
132+00	66.2	
	South Pier	
132+25	67.9	
132+03		61.6
131+98	67.6	
131+80		60.8
131+76	64.8	
131+58	65.2	64.6
131+26		63.0
131+24	65.4	
130+86		65.6
130+77	65.1	
130+62	61.8	

Table 9
Water-Surface Elevations, Type 7 Design, San Juan Creek, Q_{sj} 35,000 cfs (980 cu m/sec), Q_{tr} 5,000 cfs (140 cu m/sec)

Station	Invert	Top of Slope	Left Bank	Center Line	Right Bank
149+54	66.53	79.33	79.5	80.4	80.8
149+00	66.32	79.12	80.4	80.2	81.6
148+00	65.92	78.72	79.9	80.0	81.3
147+00	65.52	78.32	79.8	79.2	79.8
146+00	65.12	77.92	78.0	78.8	76.8
145+00	64.72	77.52	78.5	72.9	73.6
144+00	63.71	77.39	78.3	72.5	71.3
143+00	62.71	77.27	74.2	70.8	71.0
142+00	62.01	77.01	70.5	70.9	70.1
141+00	61.55	77.70	71.5	70.4	70.6
140+00	61.12	76.00	73.8	67.0	72.0
139+00	60.72	75.72	73.6	73.0	72.0
138+00	60.25	75.25	70.0	70.0	70.6
137+00	58.46	73.46	68.8	68.1	71.2
136+00	57.64	77.64	66.1	67.4	70.0
135+00	56.82	76.82	66.4	64.6	68.6
134+00	56.0	76.00	65.0	63.4	68.0
133+00	55.65	75.65	66.7	67.6	69.1
132+00	55.30	75.30	67.5	65.3	66.3
131+00	54.95	74.95	63.9	64.0	69.2
130+00	54.60	74.60	69.4	71.5	74.7
129+00	54.25	74.25	71.5	72.1	74.7
128+00	53.90	73.90	63.2	63.4	67.0
127+00	53.70	73.70	62.2	64.0	63.5
126+00	53.51	73.51	64.0	63.7	66.2
125+00	53.31	73.31	64.2	64.4	67.4
124+00	53.11	73.11	66.0	65.7	67.4
123+00	52.91	72.91	66.8	66.9	66.6
122+00	52.72	72.72	67.0	64.7	66.9
121+00	52.52	72.52	66.2	63.4	65.3
120+00	51.99	71.99	62.2	59.3	62.0

(Continued)

Table 9 (Concluded)

Station	Invert	Top of Slope	Left Bank	Center Line	Right Bank
119+00	51.46	71.46	60.6	59.3	60.7
118+00	50.93	70.93	61.1	59.7	59.5
117+00	50.39	70.39	61.3	57.5	61.0
116+50	50.16	68.19	61.3	61.5	60.5
116+00	49.86	67.89	61.0	59.2	60.1
114+00	48.70	65.20	59.0	58.1	59.2
113+00	48.26	64.76	59.6	58.2	58.9
112+00	47.82	64.32	59.6	60.6	58.4
111+00	47.38	63.88	57.4	55.3	57.4
110+00	46.94	63.44	56.4	54.3	57.2
109+00	46.50	63.00	55.4	55.2	56.5
108+00	46.06	62.56	55.5	53.8	56.1
107+00	45.62	62.12	55.4	52.9	55.3
106+00	45.18	61.68	54.5	53.3	55.1
105+00	44.74	61.24	55.2	54.5	56.1

Table 10
Water-Surface Elevations, Type 7 Design, Proposed Railroad Bridge, San Juan Creek, Q_{sj} 35,000 cfs (980 cu m/sec), Q_{tr} 5,000 cfs (140 cu m/sec)

Station	Left Side of Pier	Right Side of Pier
	North Pier	
134+17	64.5	
133+95	67.0	
133+86		69.6
133+74	65.4	
133+58		64.5
133+41	64.5	65.1
133+07	63.9	67.1
133+06	64.1	
	Center Pier	
133+30	66.0	
132.99		68.9
132+94	72.3	
132+78		62.9
132+69	68.1	
132+53		64.1
132+44	65.5	
132+29		67.0
132+11	67.6	
132+08		65.2
132+00	63.9	
	South Pier	
132+25	66.8	
132+03		67.5
131+98	69.5	
131+85		62.4
131+76	63.9	
131+67		63.9
131+35	64.1	
131+26		62.3

(Continued)

Table 10 (Concluded)		
Station	**Left Side of Pier**	**Right Side of Pier**
130+86		64.6
130+79	64.1	
130+62	61.1	

Table 11
Water-Surface Elevations, Type 7 Design, San Juan Creek, Q_{sj} 17,000 cfs (476 cu m/sec) Q_{tr} 17,000 cfs (476 cu m/sec)

Station	Invert	Top of Slope	Left Bank	Center Line	Right Bank
149+36	66.46	79.26	74.9	75.4	75.9
149+00	66.32	79.12	75.7	75.0	76.2
148+00	65.92	78.72	75.3	76.0	76.2
147+00	65.52	78.32	75.1	74.3	74.0
146+00	65.12	77.92	72.6	73.5	70.9
145+00	64.72	77.52	73.6	70.0	70.7
144+00	63.71	77.39	73.2	69.6	69.0
143+00	62.71	77.27	70.1	68.2	68.6
142+00	62.01	77.01	67.7	67.6	67.2
141+00	61.55	77.70	68.0	67.3	67.1
140+00	61.12	76.00	69.1	68.5	68.1
139+00	60.72	75.72	69.2	67.7	66.7
138+00	60.25	75.25	66.9	66.1	67.0
137+00	58.46	73.46	64.7	63.7	65.8
136+00	57.64	77.64		63.1	64.9
135+00	56.82	76.82	63.1	62.1	64.7
134+00	56.0	76.00	62.8	61.0	65.3
133+00	55.65	75.65	63.5	64.5	63.7
132+00	55.30	75.30	64.3	61.5	65.8
131+00	54.95	74.95	63.7	64.1	66.6
130+00	54.60	74.60	70.8	71.0	73.8
129+00	54.25	74.25	70.3	70.3	82.2
128+00	53.90	73.90	64.2	64.3	66.2
127+00	53.70	73.70	63.7	64.7	64.6
126+00	53.51	73.51	64.7	65.0	62.4
125+00	53.31	73.31	63.7	64.4	64.7
124+00	53.11	73.11	64.9	64.2	64.3
123+00	52.91	72.91	65.6	63.9	64.9
122+00	52.72	72.72	65.6	63.5	65.2
121+00	52.52	72.52	64.6	63.0	64.6
120+00	51.99	71.99	64.2	60.3	61.4

(Continued)

Table 11 (Concluded)

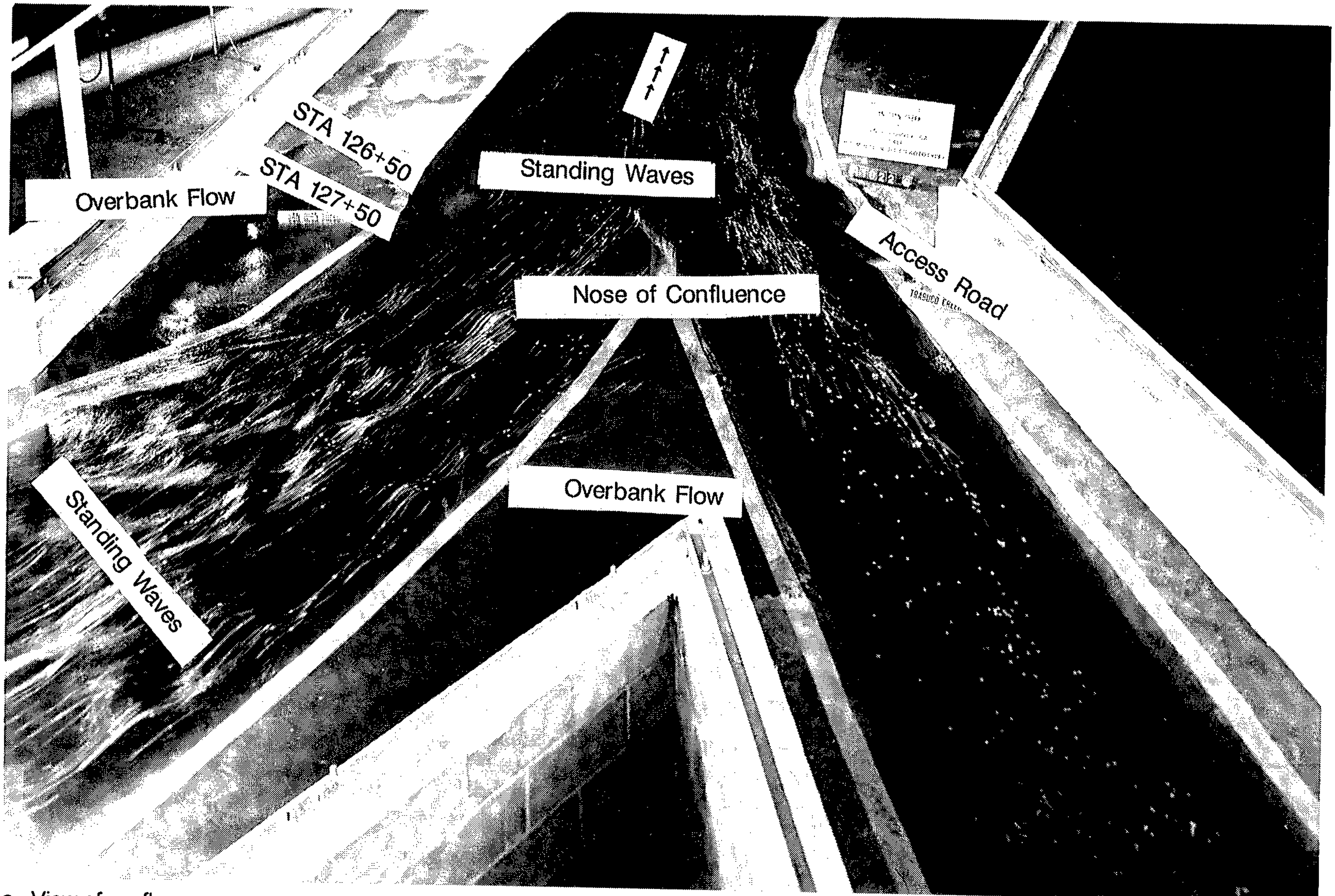
Station	Invert	Top of Slope	Left Bank	Center Line	Right Bank
119+00	51.46	71.46	63.0	60.0	59.5
118+00	50.93	70.93	61.2	59.2	59.4
117+00	50.39	70.39	62.0	59.4	60.6
116+50	50.16	68.19	61.9	60.9	60.2
116+00	49.86	67.89	58.2	59.1	59.2
115+00	49.33	65.38	60.2	57.2	58.2
114+00	48.70	65.20	59.2	57.5	57.1
113+00	48.26	64.76	60.0	57.6	57.7
112+00	47.82	64.32	60.0	56.9	57.9
111+00	47.38	63.88	57.7	55.9	56.9
110+00	46.94	63.44	57.0	54.3	56.2
109+00	46.50	63.00	55.9	55.0	55.9
108+00	46.06	62.56	56.4	54.1	55.6
107+00	45.62	62.12	54.7	52.9	54.5
106+00	45.18	61.68	55.2	53.0	53.6
105+00	44.74	61.24	54.8	52.9	55.4

Table 12
Water-Surface Elevations, Type 7 Design, Proposed Railroad Bridge, San Juan Creek, Q_{sj} 17,000 cfs (476 cu m/sec), Q_{tr} 17,000 cfs (476 cu m/sec)

Station	Left Side of Pier	Right Side of Pier
	North Pier	
134+17	62.0	
134+15	64.3	
133+97		67.3
133+88	61.8	
133+72		61.9
133+59	61.3	
133+43		63.1
133+31	65.5	
133+18		61.6
133+09	63.4	
133+06	61.2	
	Center Pier	
133+30	63.5	
133+08	67.3	
133+07		63.4
132+94		65.5
132+90	64.1	
132+74	62.2	
132+65		60.8
132+40	65.8	
132+36		63.5
132+15	66.0	
132+13		61.4
132+00	60.4	
	South Pier	
132.25	64.3	
132+07		65.5
132+03	60.6	

(Continued)

Table 12 (Concluded)		
Station	**Left Side of Pier**	**Right Side of Pier**
131+89	64.9	
131+82		60.8
131+69	65.6	
131+40		64.2
131+35	64.0	
130+79	63.6	63.7
130+62	63.1	

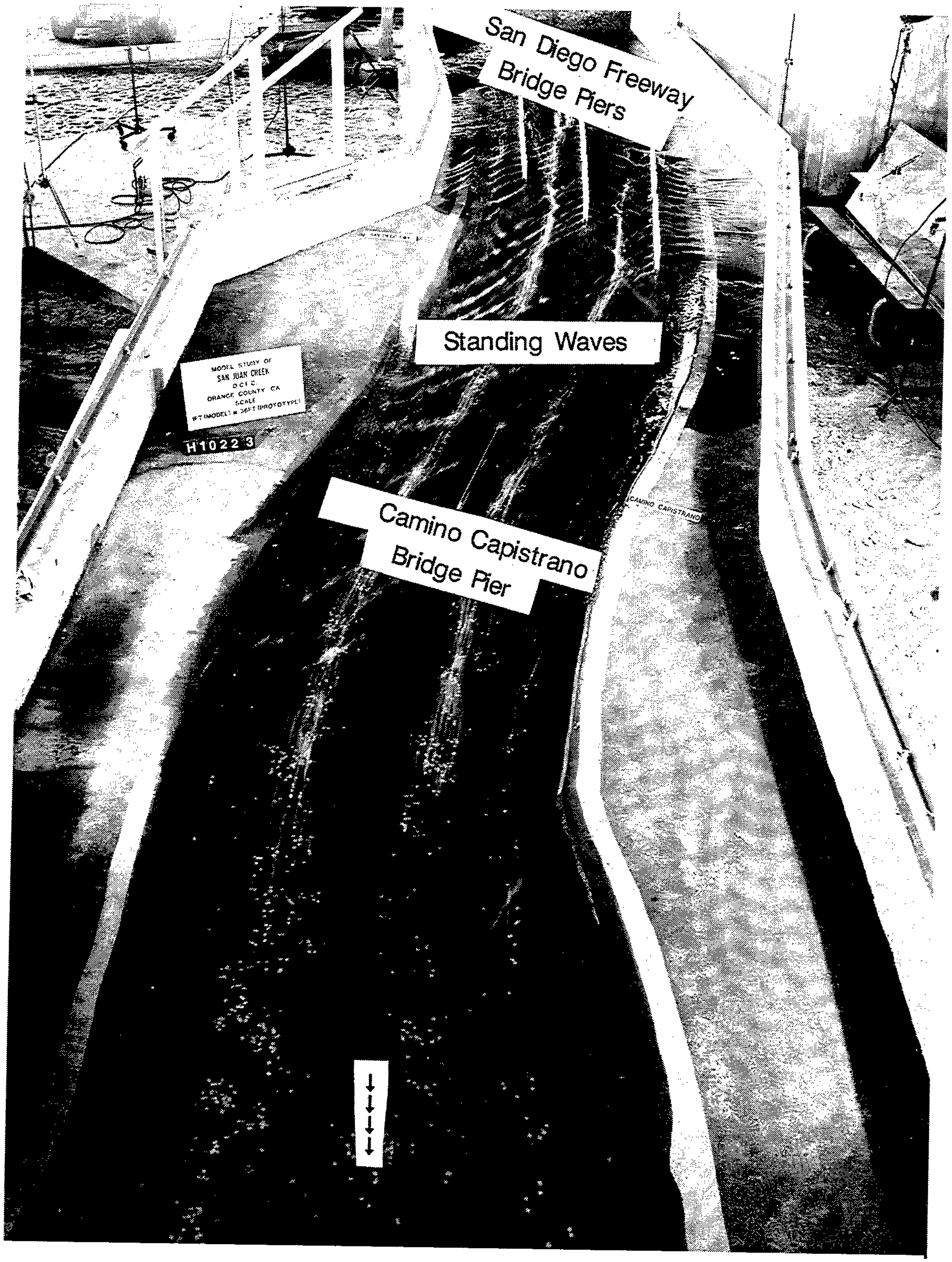


a. View of confluence

Photo 1. San Juan Creek, type 1 design, looking downstream at the confluence with Trabuco Creek, design discharges Q_{sj} 42,000 cfs (1,176 cu m/sec); Q_{tr} 17,000 cfs (476 cu m/sec). Standing waves observed were created by the railroad bridge piers and the abrupt expansion of the channel width. Overbank flow was also observed along the left and right banks. (Continued)

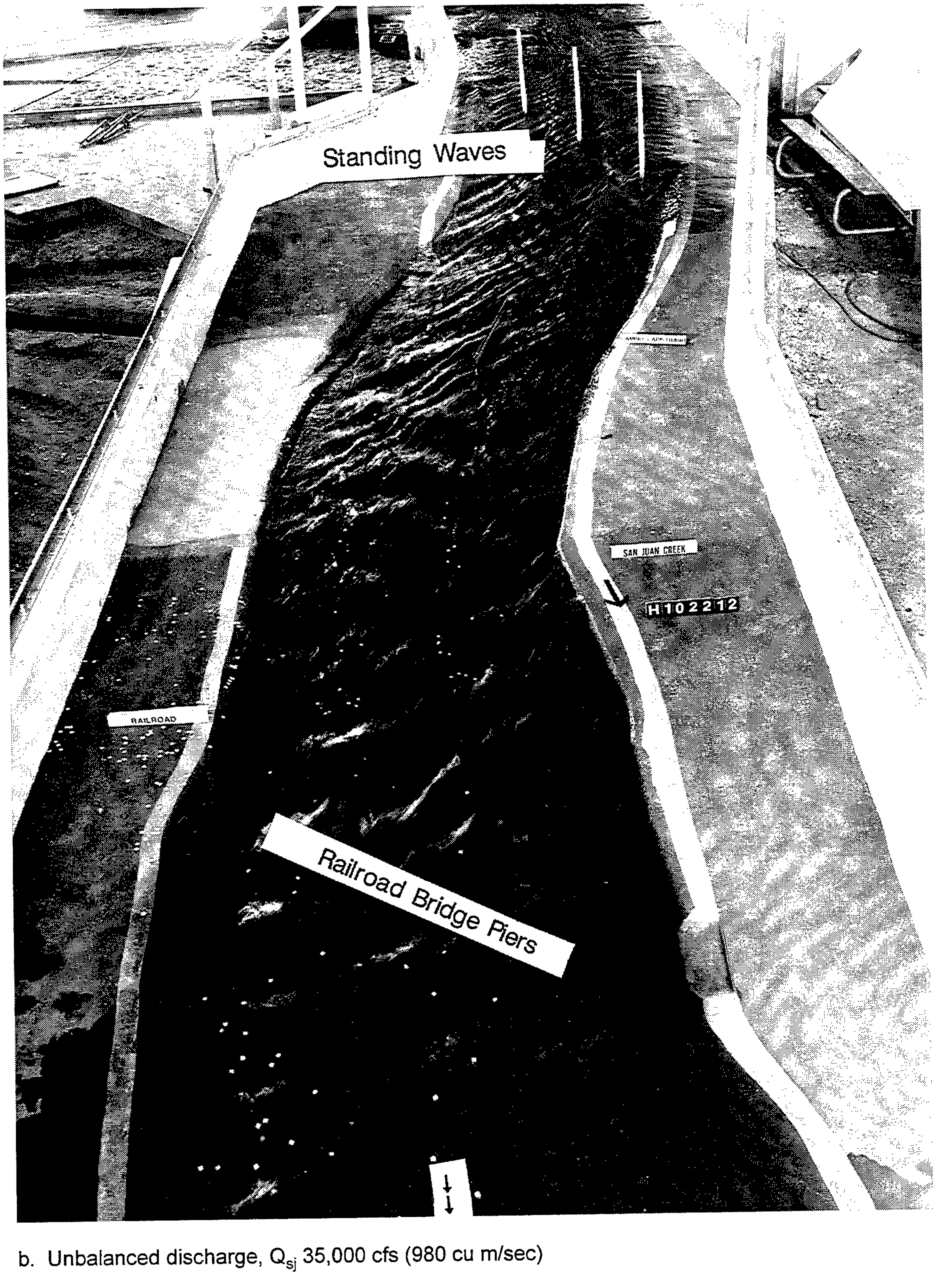
b. View from San Juan Creek

Photo 1. (Concluded)



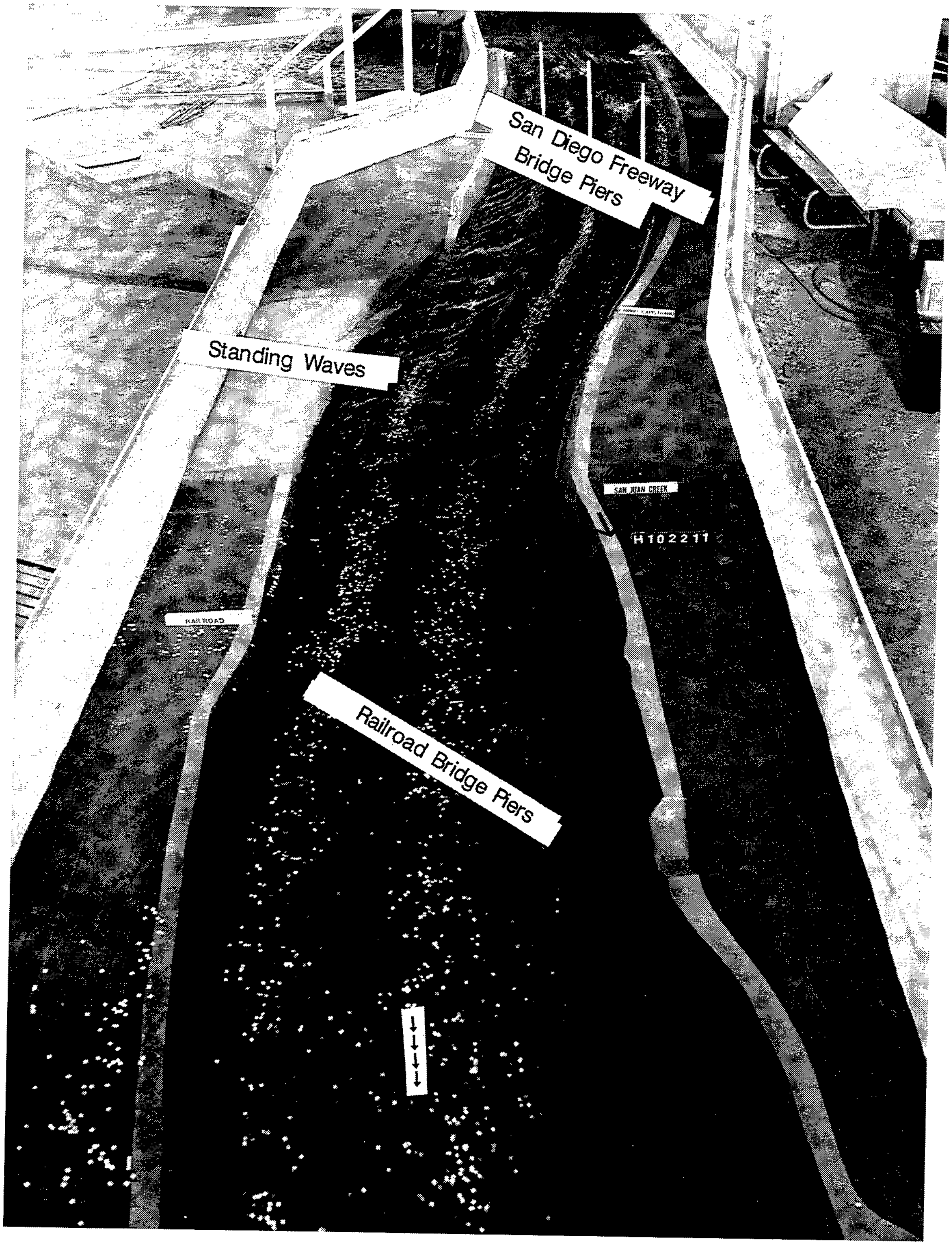
a. Design discharge, Q_{sj} 42,000 cfs (1,176 cu m/sec)

Photo 2. San Juan Creek, type 1 design, oblique standing waves observed between the San Diego Freeway bridge piers (Sheet 1 of 3)



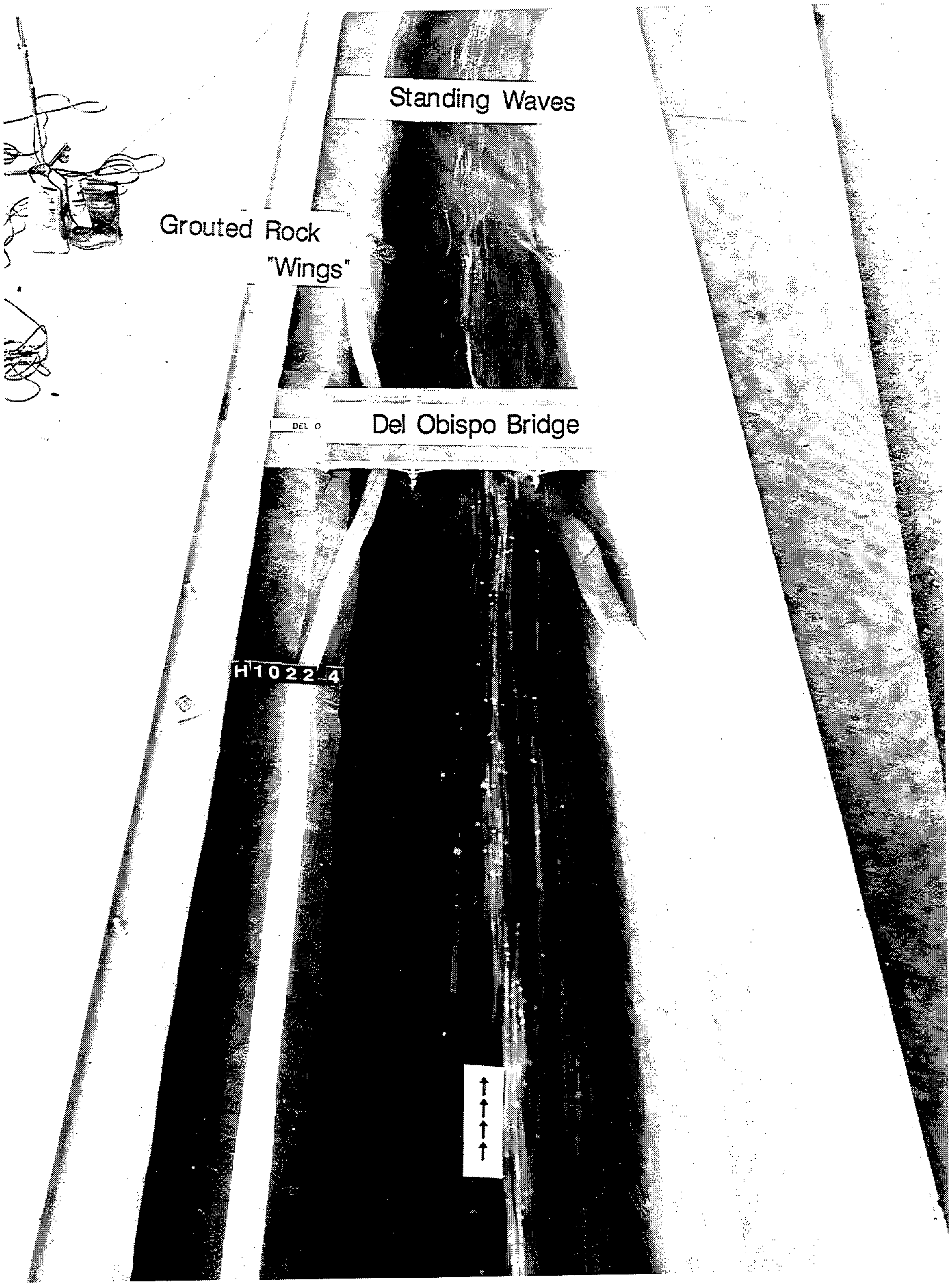
b. Unbalanced discharge, Q_{sj} 35,000 cfs (980 cu m/sec)

Photo 2. (Sheet 2 of 3)



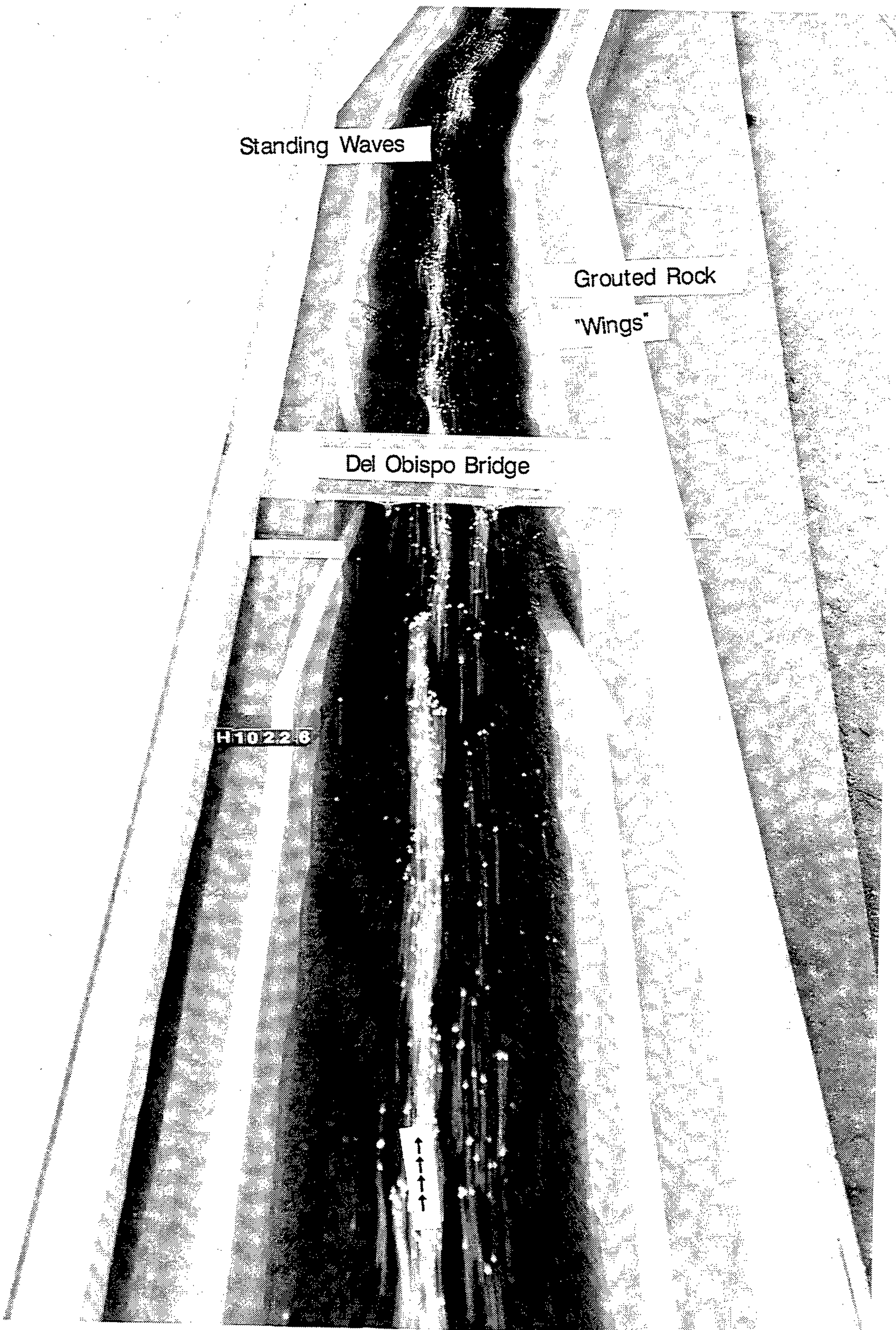
c. Balanced discharge, Q_{sj} 17,000 cfs (476 cu m/sec)

Photo 2. (Sheet 3 of 3)



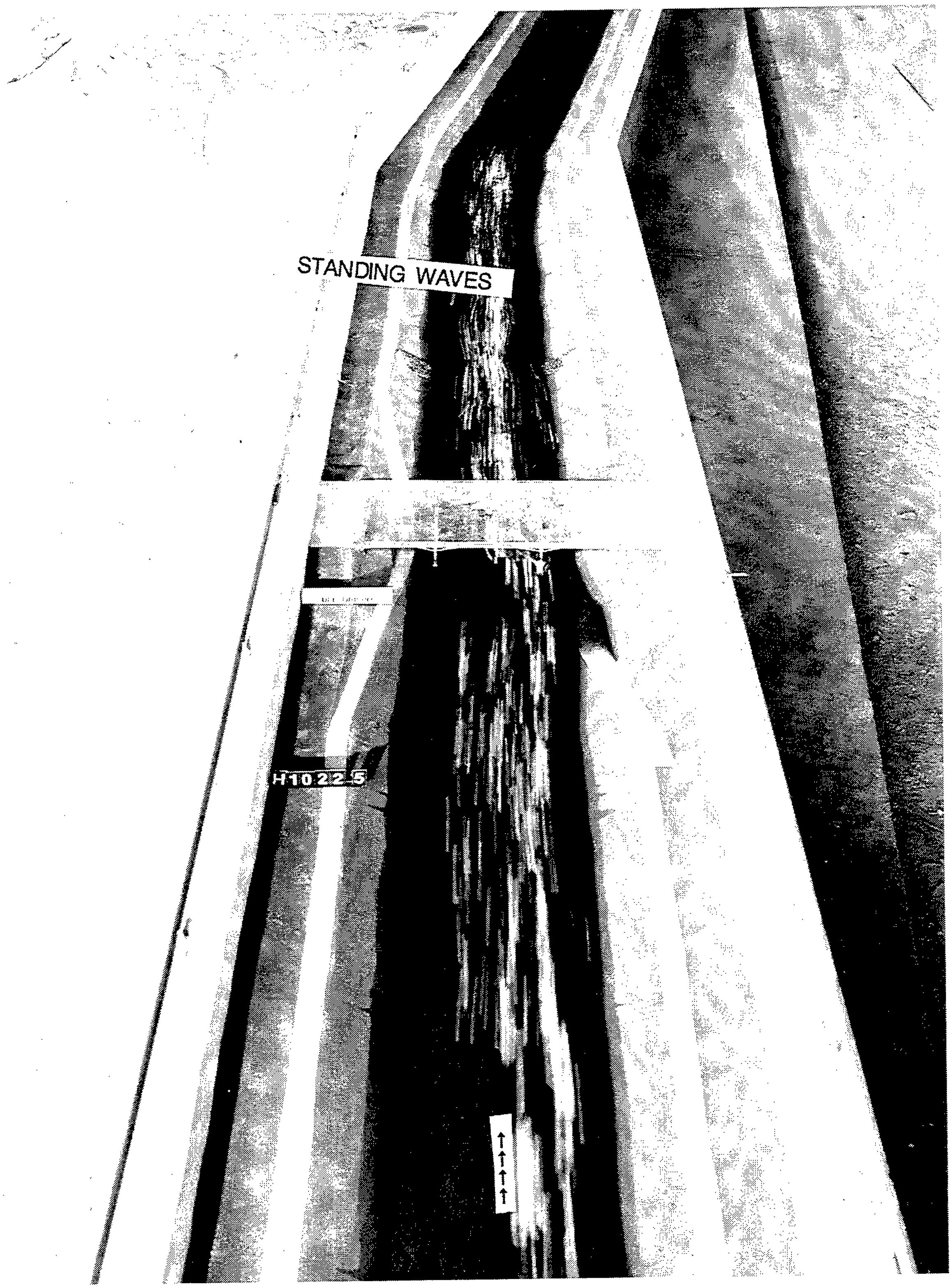
a. Design discharge, Q_{tr} 17,000 cfs (476 cu m/sec)

Photo 3. Trabuco Creek, type 1 design, looking downstream at the Del Obispo Bridge. Oblique standing waves observed downstream of the grade stabilizer and created by the grouted rock wings. (Sheet 1 of 3)



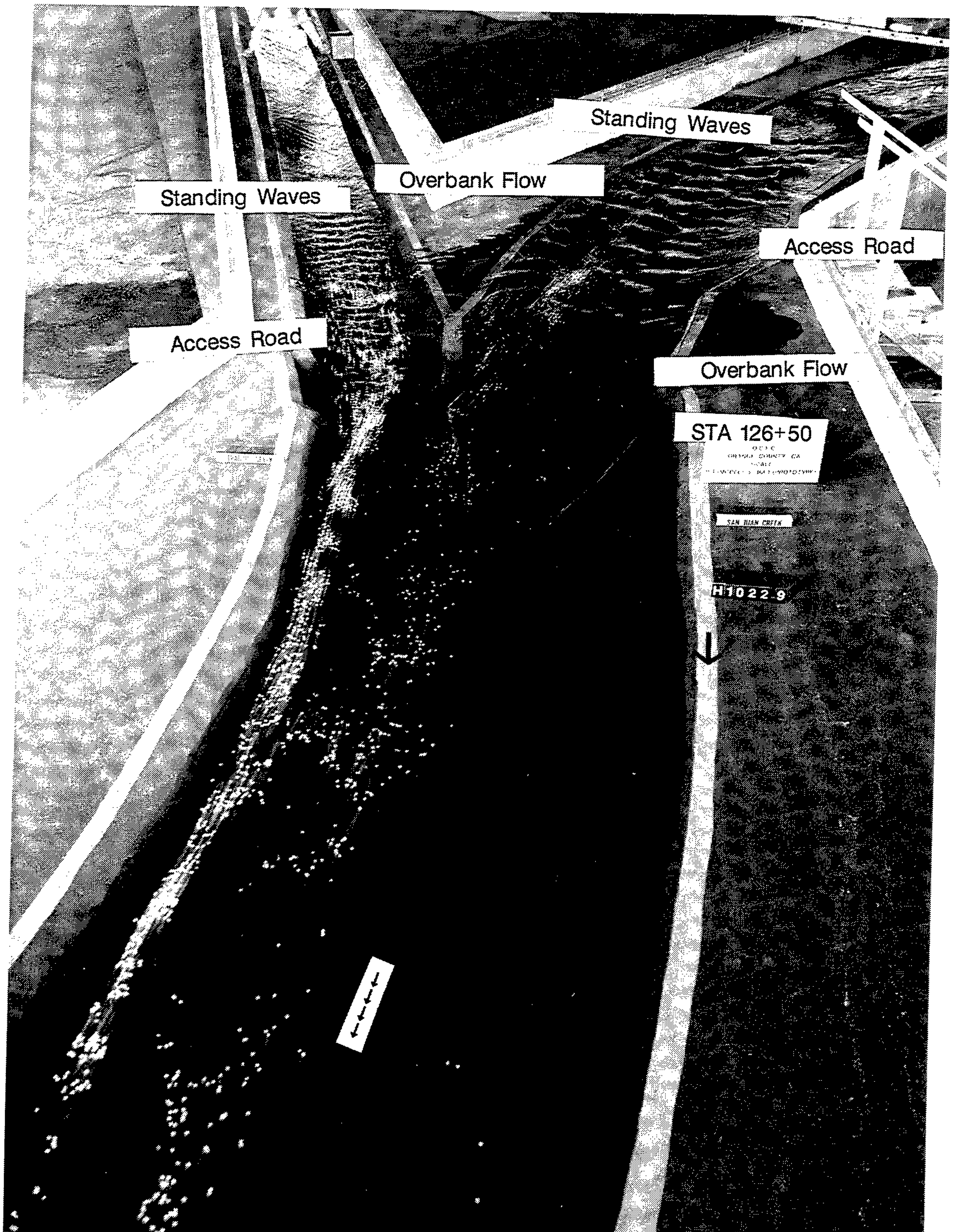
b. Unbalanced discharge, Q_{tr} 5,000 cfs (140 cu m/sec)

Photo 3. (Sheet 2 of 3)



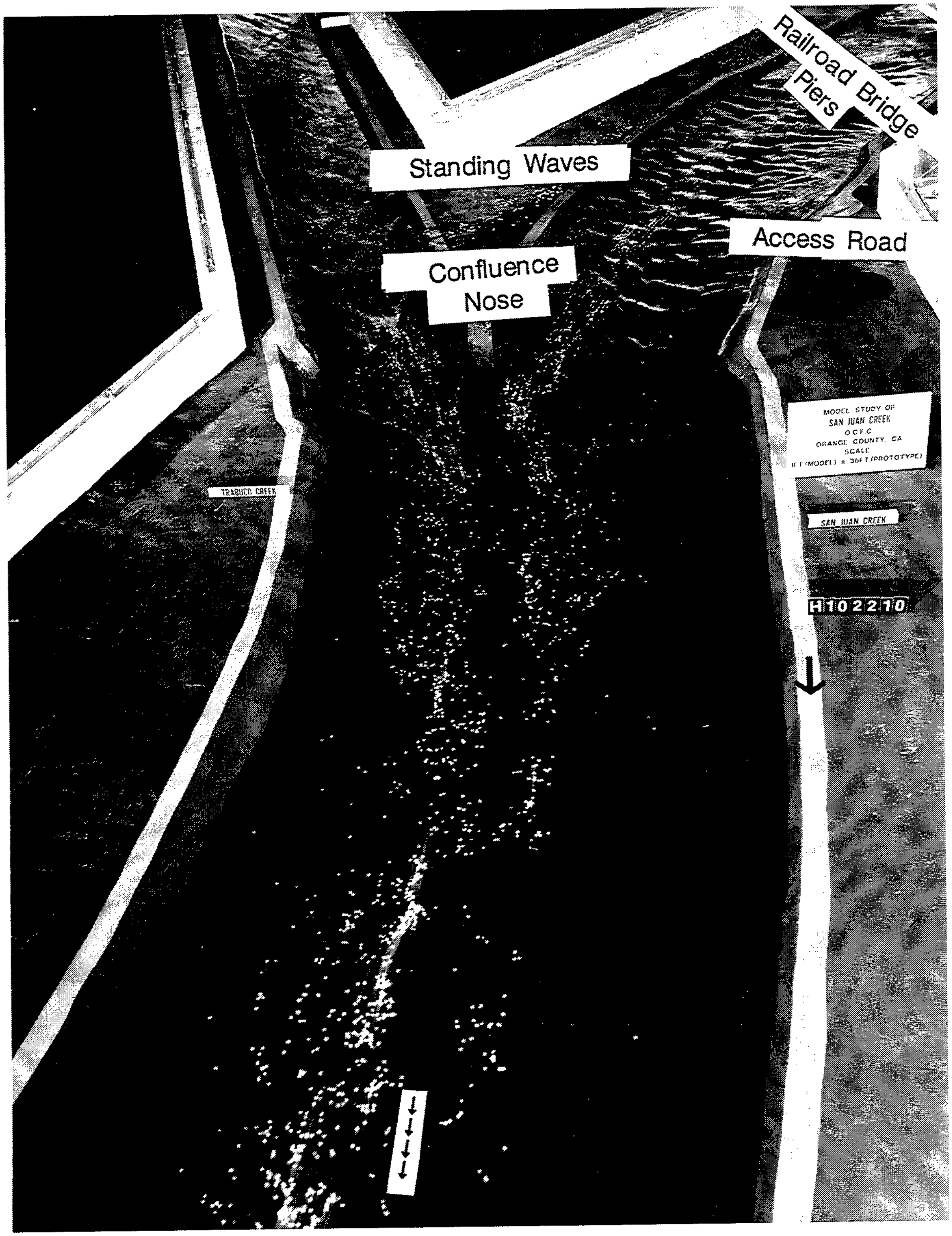
c. Balanced discharge, Q_{tr} 17,000 cfs (476 cu m/sec)

Photo 3. (Sheet 3 of 3)



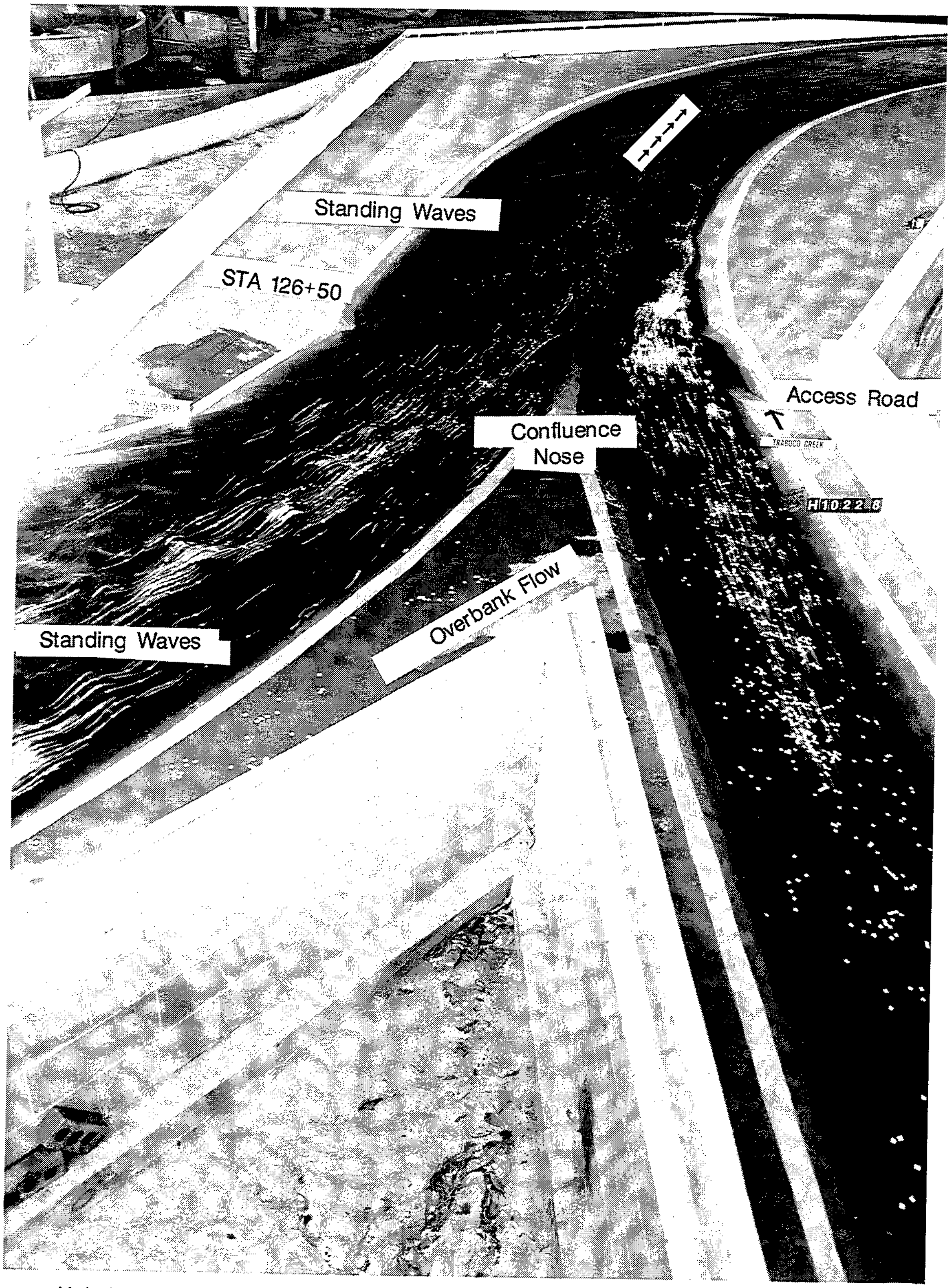
a. Unbalanced discharges, Q_{sj} 35,000 cfs (980 cu m/sec) and Q_{tr} 5,000 cfs (140 cu m/sec)

Photo 4. San Juan Creek, type 1 design, looking upstream at the confluence with Trabuco Creek. Standing waves observed downstream of railroad bridge piers, created by the bridge piers and access roads on San Juan and Trabuco Creeks. (Continued)



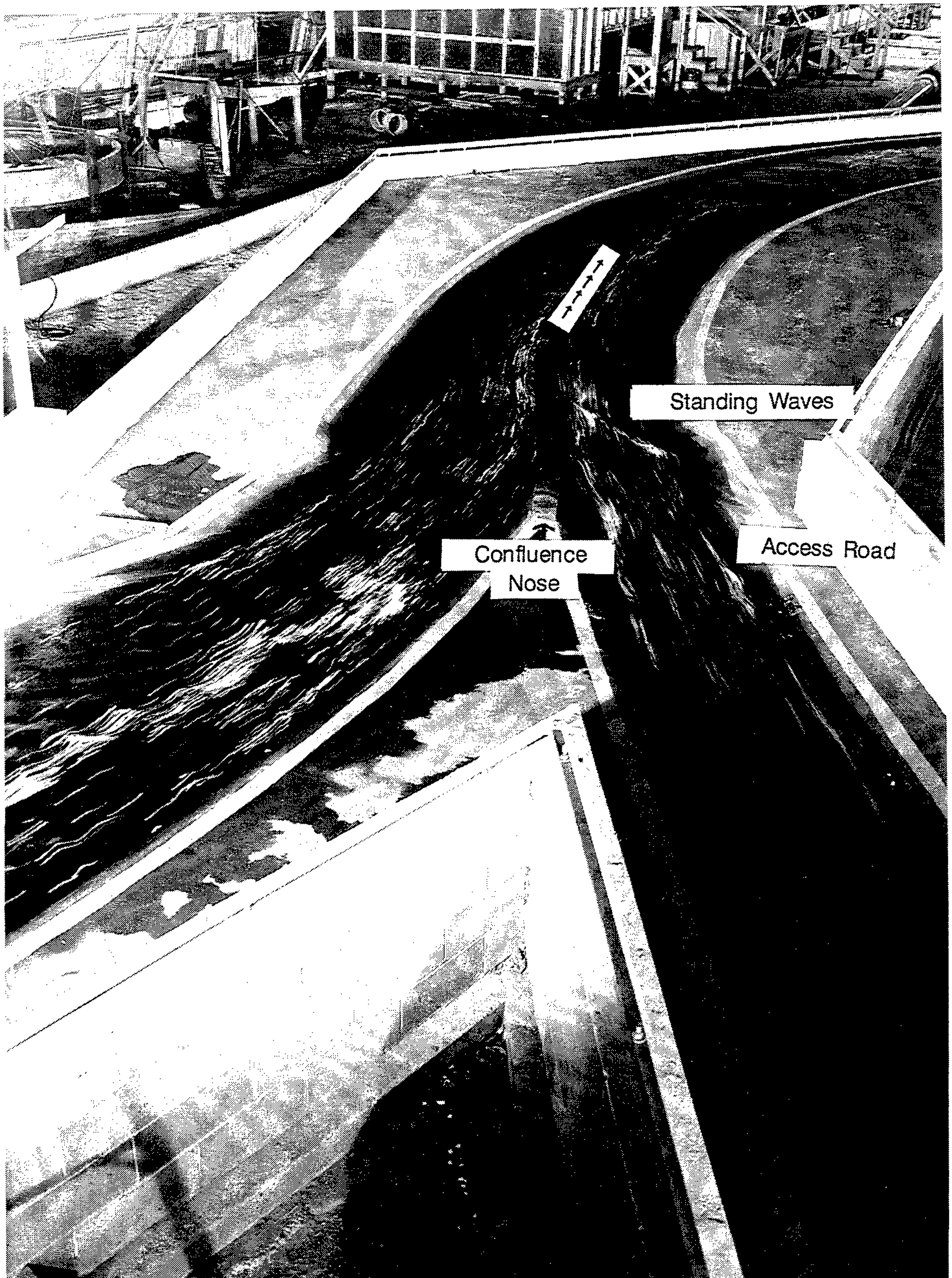
b. Balanced discharges, Q_{sj} 17,000 cfs (476 cu m/sec) and Q_{tr} 17,000 cfs (476 cu m/sec)

Photo 4. (Concluded)



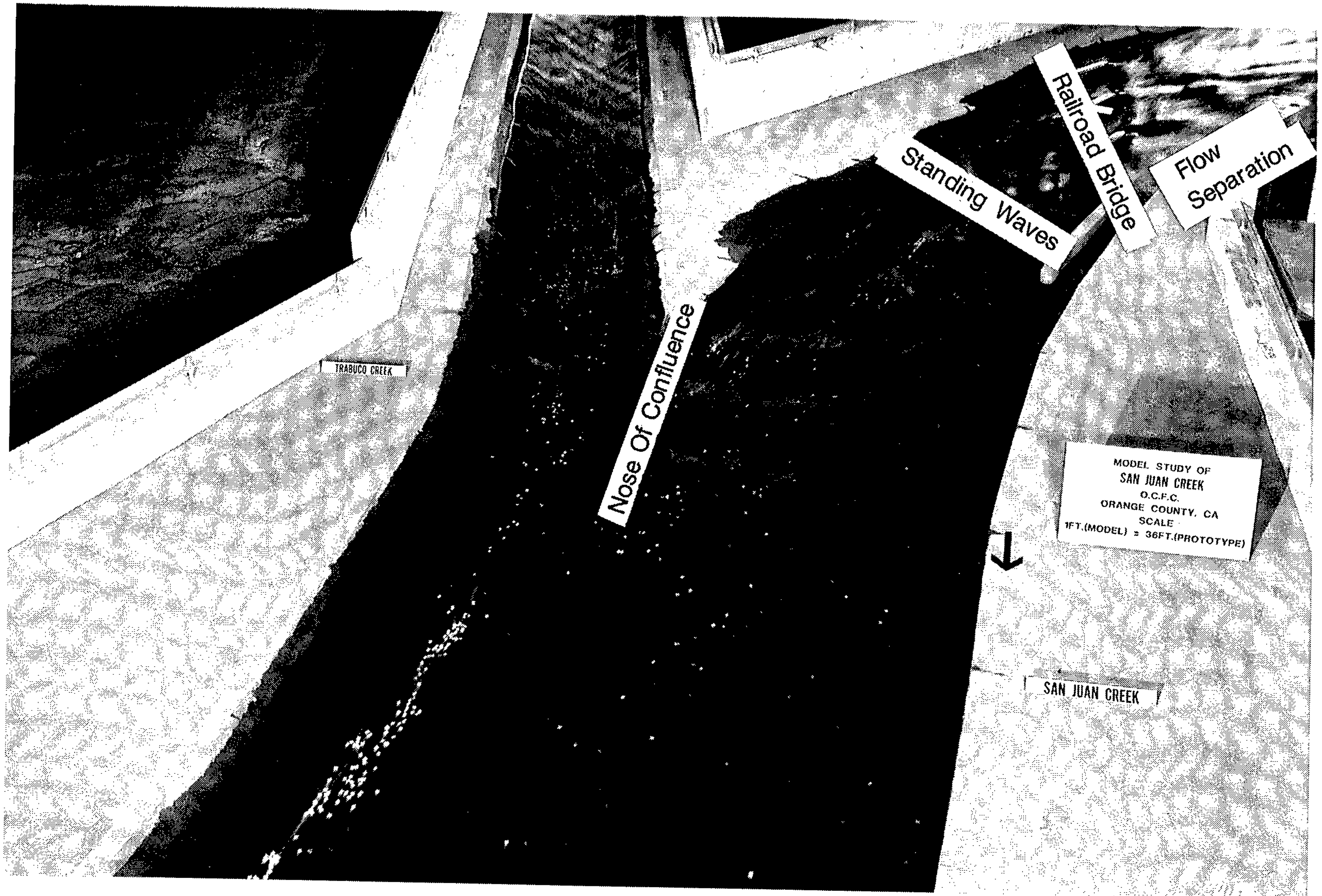
a. Unbalanced discharges, Q_{sj} 35,000 cfs (980 cu m/sec) and Q_{tr} 5,000 cfs (140 cu m/sec). Diagonal standing wave observed extending across the channel.

Photo 5. San Juan Creek, type 1 design, looking downstream at the confluence with Trabuco Creek (Continued)



b. Balanced discharges, Q_{sj} 17,000 cfs (476 cu m/sec) and Q_{tr} 17,000 cfs (476 cu m/sec). Oblique standing wave observed in Trabuco Creek, created by access road and nose of confluence.

Photo 5. (Concluded)

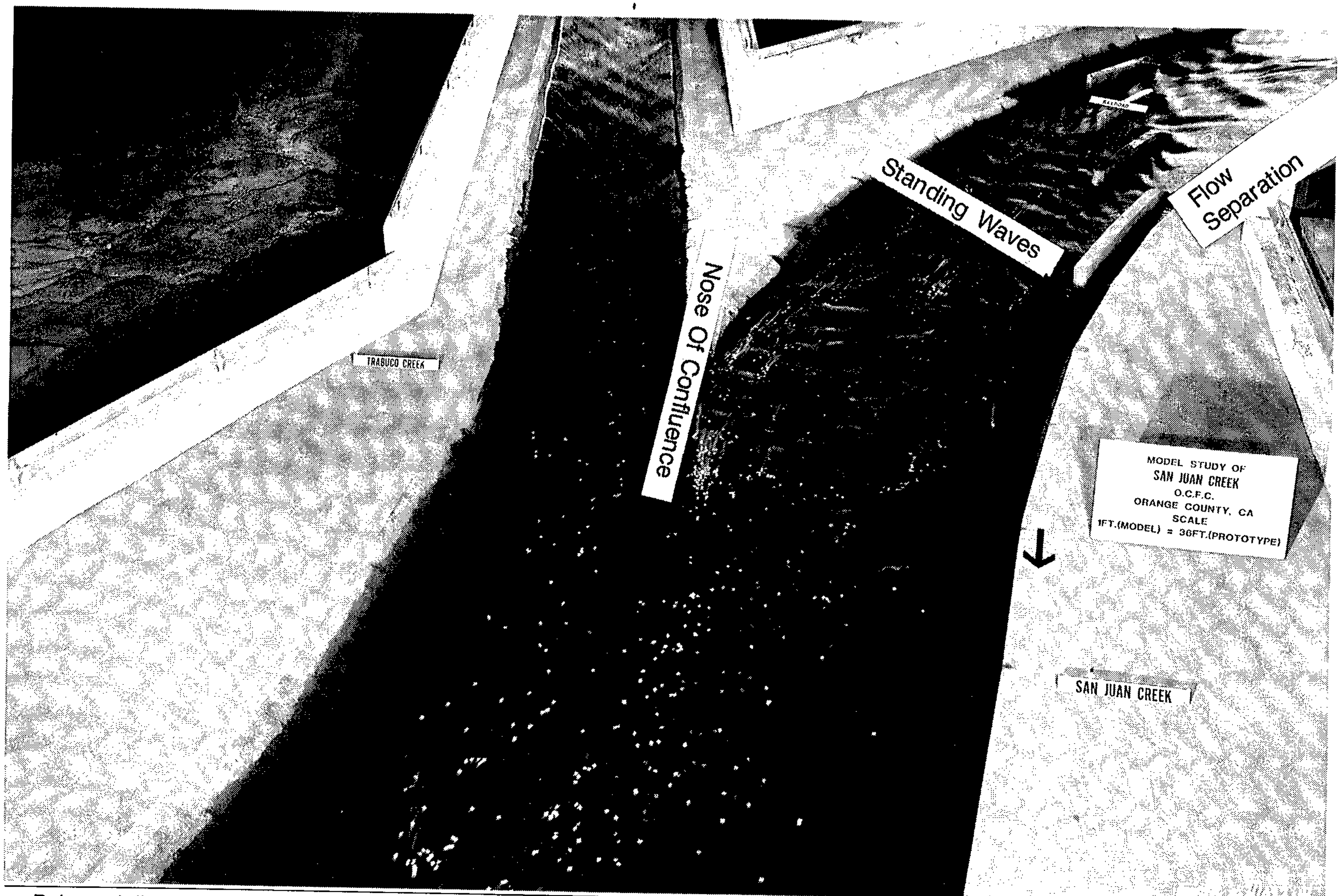


a. Design discharges, Q_{sj} 42,000 cfs (1,176 cu m/sec) and Q_{tr} 17,000 cfs (476 cu m/sec)

Photo 6. San Juan Creek, type 2 design, looking upstream at the confluence with Trabuco Creek. Standing waves observed were created by the railroad bridge piers. Flow separation observed on right bank forced flow toward left bank (Sheet 1 of 3)

b. Unbalanced discharges, Q_{sj} 35,000 cfs (980 cu m/sec) and Q_{tr} 5,000 cfs (140 cu m/sec)

Photo 6. (Sheet 2 of 3)

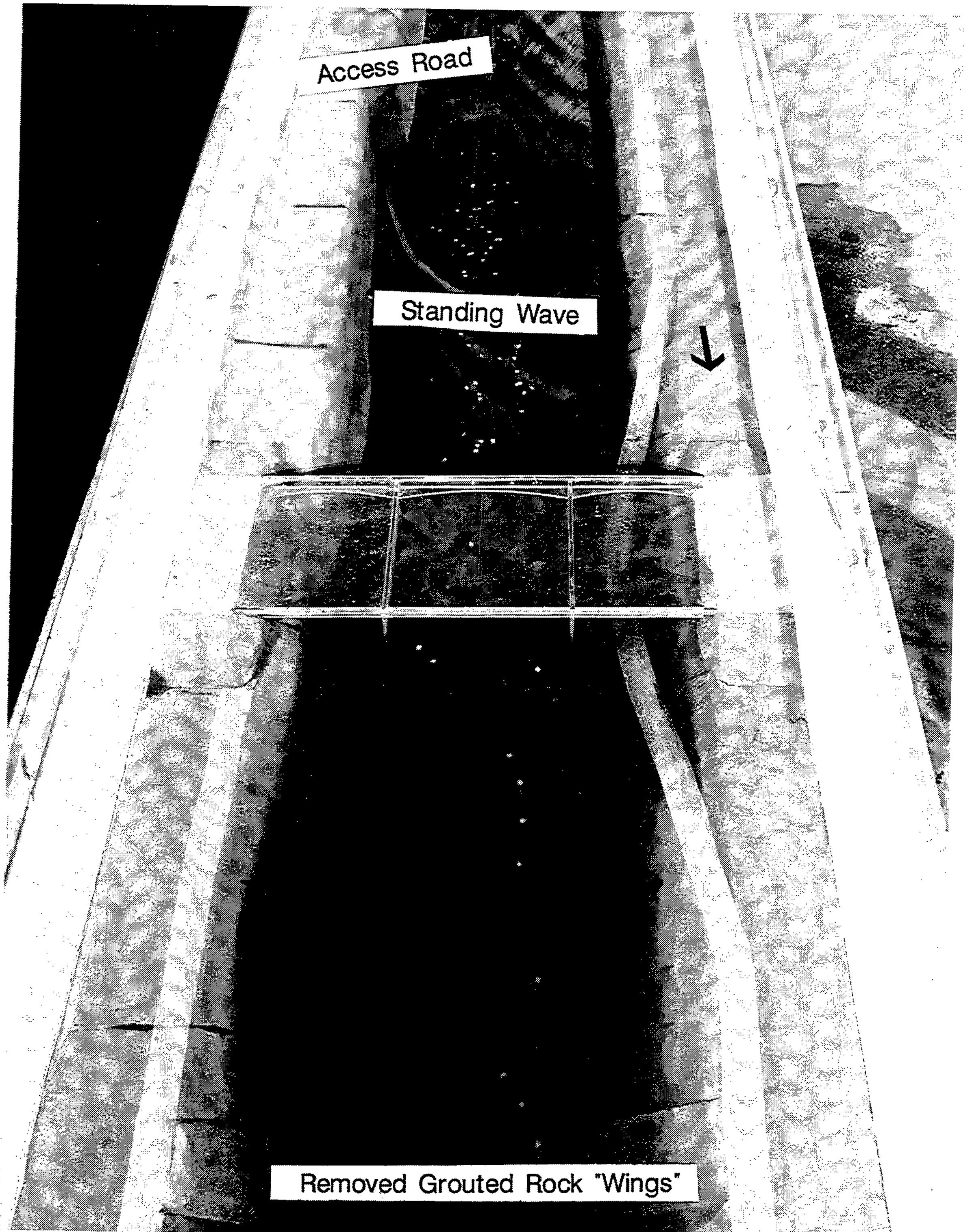


c. Balanced discharges, Q_{sj} 17,000 cfs (476 cu m/sec) and Q_{tr} 17,000 cfs (476 cu m/sec)

Photo 6. (Sheet 3 of 3)

a. Design discharge, Q_{tr} 17,000 cfs (476 cu m/sec)

Photo 7. Trabuco Creek, type 2 design, looking upstream at Del Obispo Bridge. The diagonal standing wave observed was created by the access road. Grouted rock wings were removed. (Sheet 1 of 3)

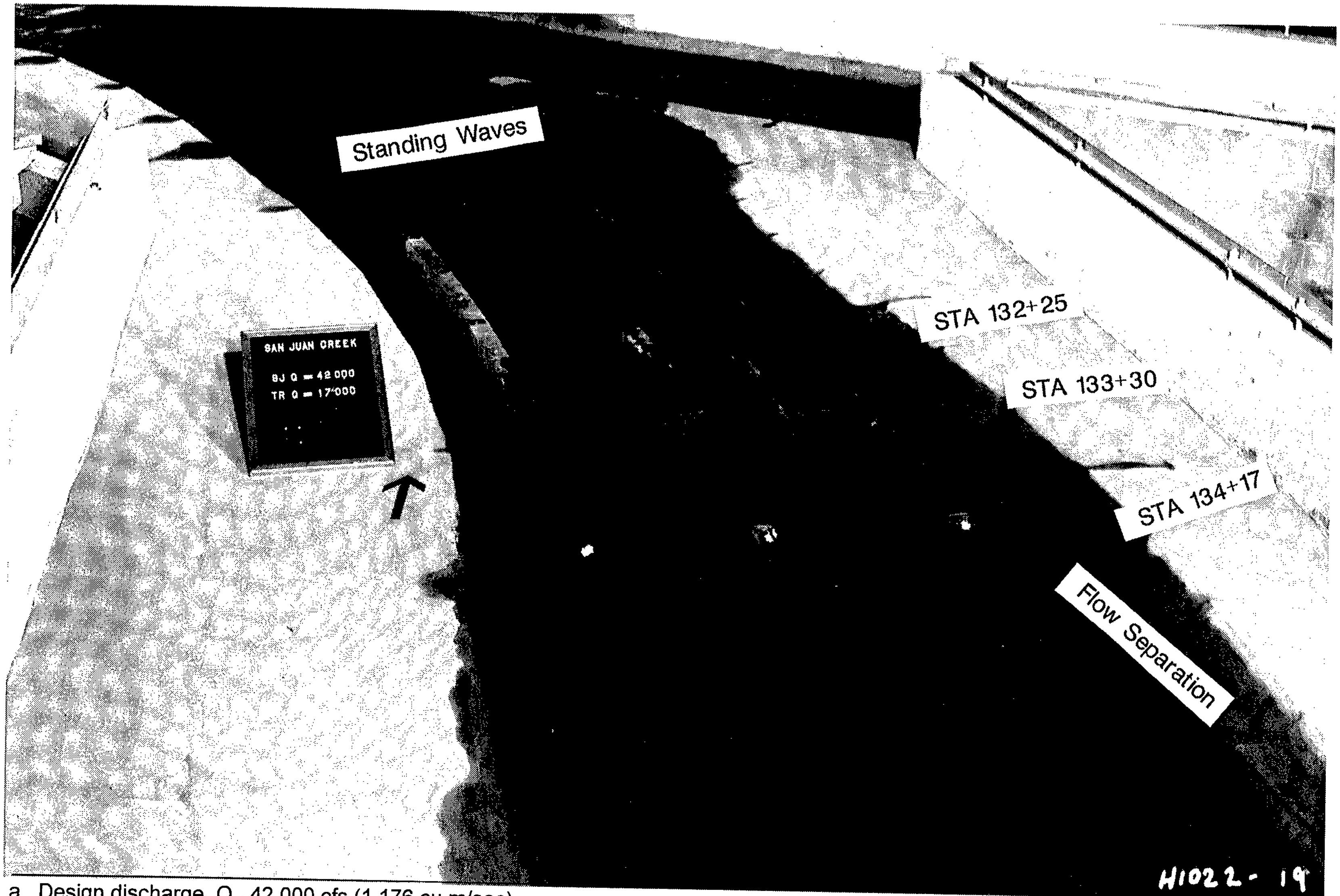


b. Unbalanced discharge, Q_{tr} 5,000 cfs (140 cu m/sec)

Photo 7. (Sheet 2 of 3)

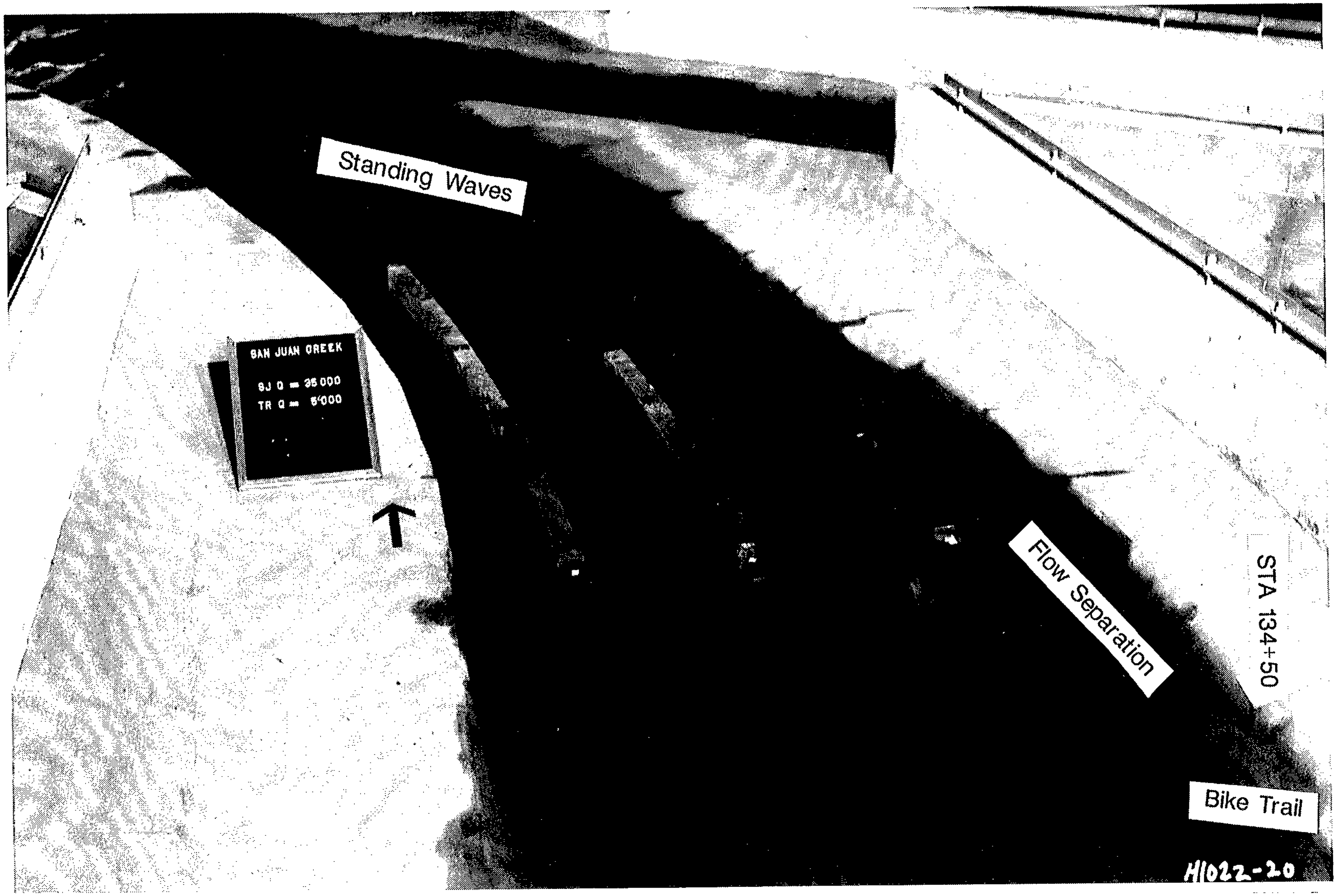
c. Balanced discharge, Q_{tr} 17,000 cfs (476 cu m/sec)

Photo 7. (Sheet 3 of 3)



a. Design discharge, Q_{sj} 42,000 cfs (1,176 cu m/sec)

Photo 8. San Juan Creek, type 6 design, flow conditions in the vicinity of the railroad bridge piers with pier extensions, downstream view. Flow separation observed on the right bank, created by the bike trail, contributed to standing waves downstream of the railroad bridge piers. A prominent standing wave extended the width of the channel, created by a decrease in the flow area. (Continued)

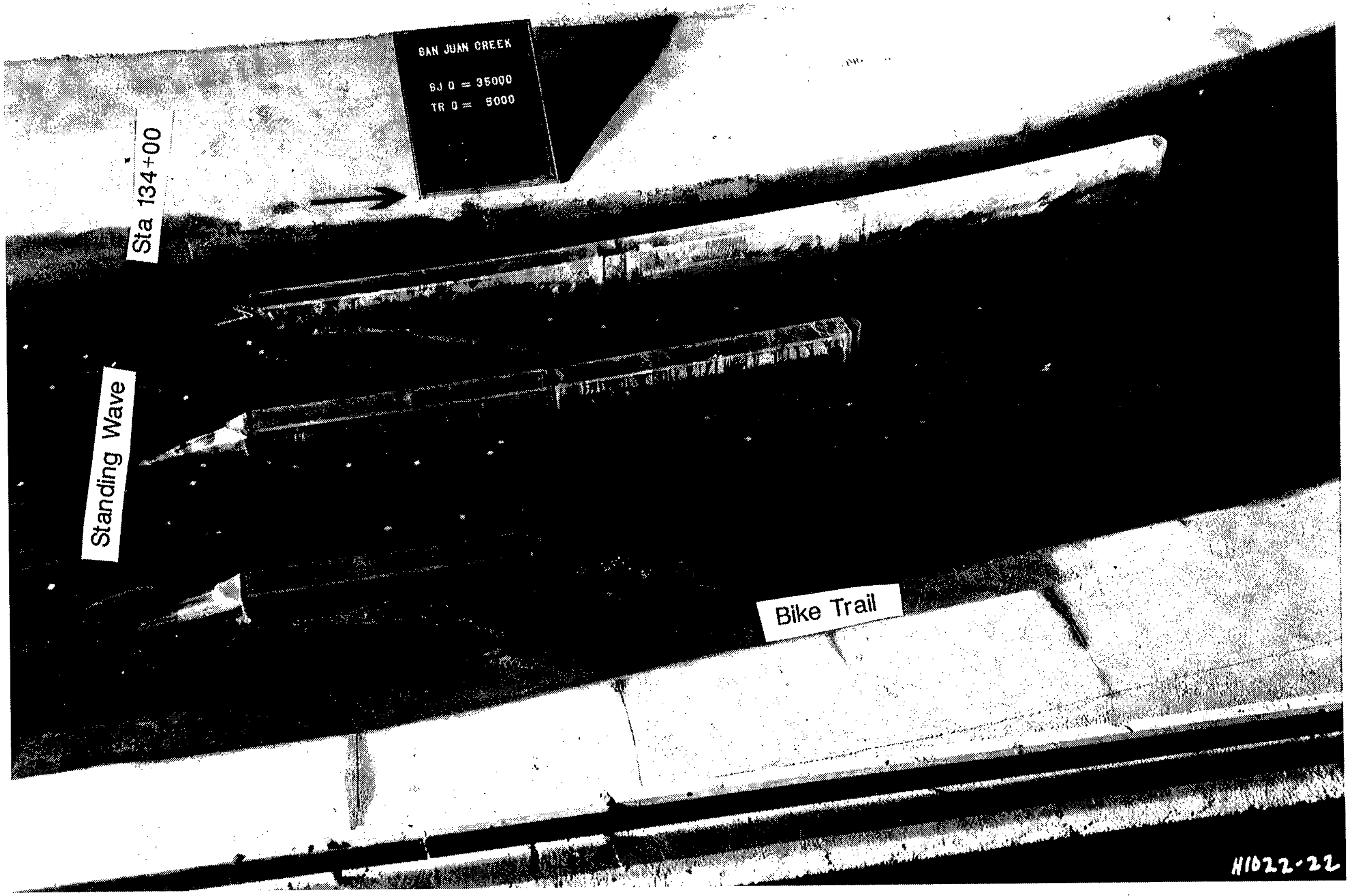


b. Unbalanced discharge, Q_{sj} 35,000 cfs (980 cu m/sec)

Photo 8. (Concluded)

a. Design discharge, Q_{sj} 42,000 cfs (1,176 cu m/sec)

Photo 9. San Juan Creek, type 6 design, flow conditions in the vicinity of the railroad bridge piers, side view. A prominent standing wave extended the width of the channel, induced by a change in slope of channel invert by a decrease in flow area. (Sheet 1 of 3)



b. Unbalanced discharge, Q_{sj} 35,000 cfs (980 cu m/sec)

Photo 9. (Sheet 2 of 3)

c. Balanced discharge, Q_{sj} 17,000 cfs (476 cu m/sec)

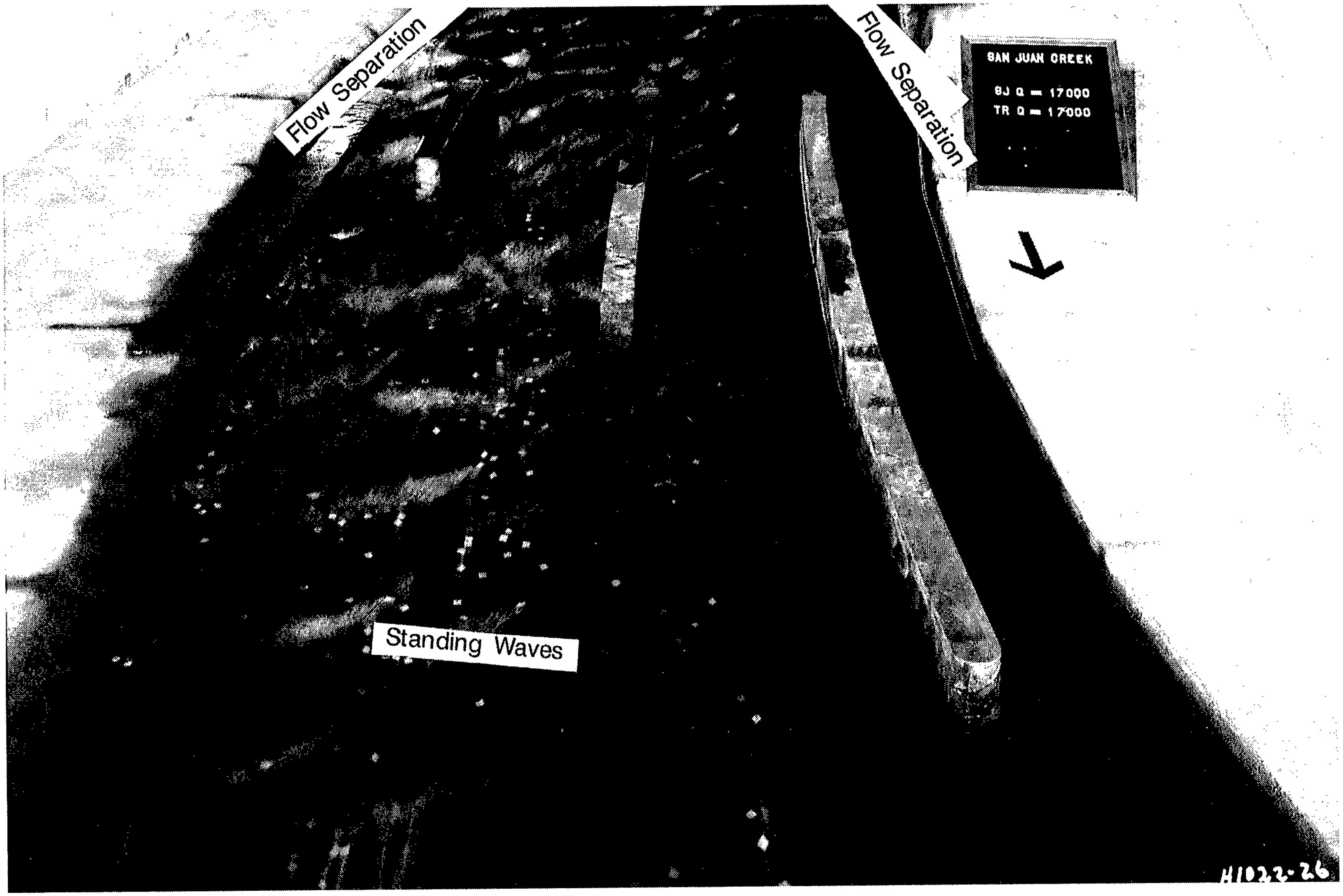
Photo 9. (Sheet 3 of 3)

a. Design discharge, Q_{sj} 42,000 cfs (1,176 cu m/sec)

Photo 10. San Juan Creek, type 6 design, flow conditions in the vicinity of the railroad bridge piers, upstream view. Standing waves observed downstream of the railroad bridge piers, created by flow separation on left and right banks and the bridge piers (Sheet 1 of 3)

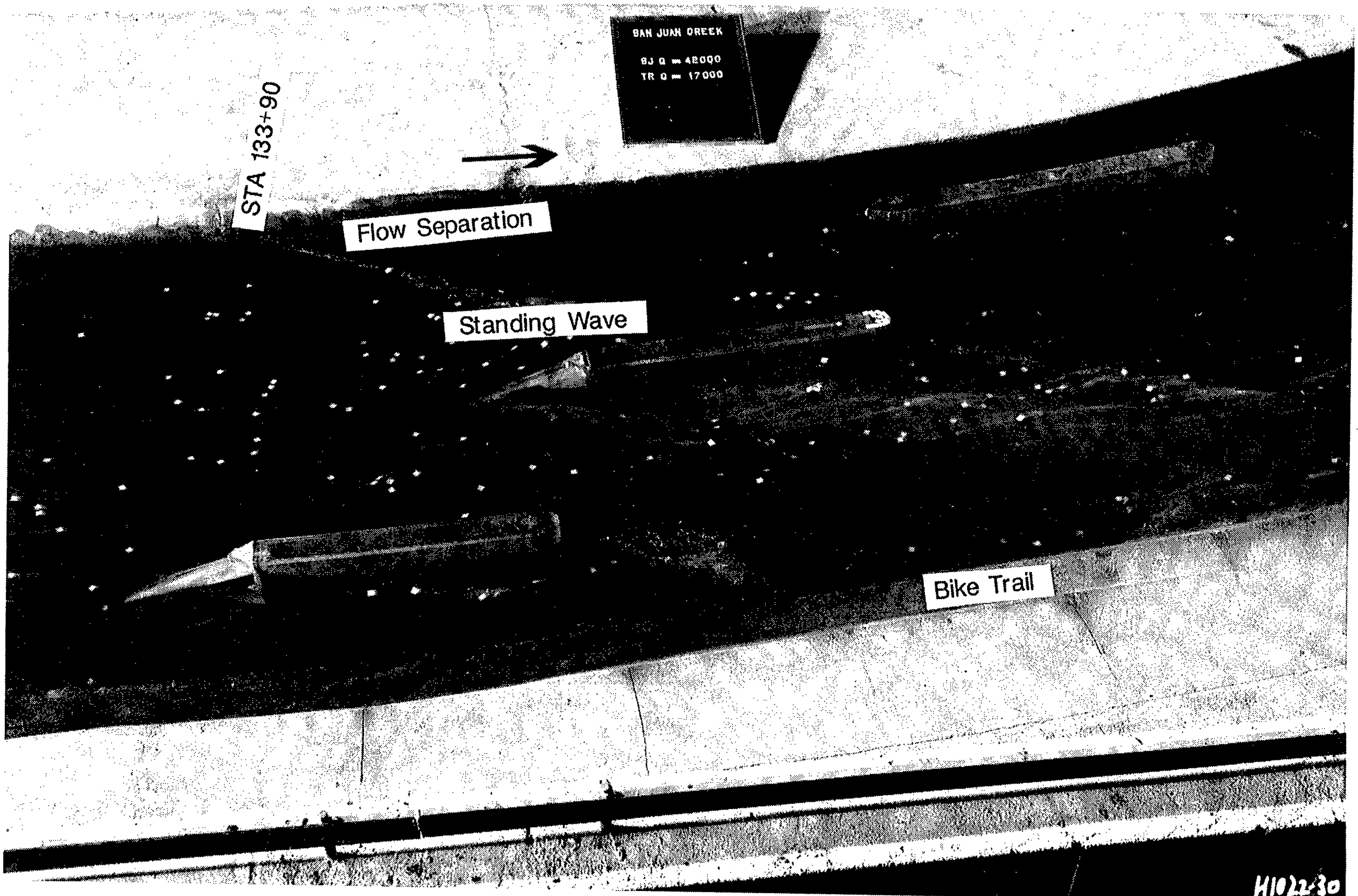
b. Unbalanced discharge, Q_{sj} 35,000 cfs (980 cu m/sec)

Photo 10. (Sheet 2 of 3)



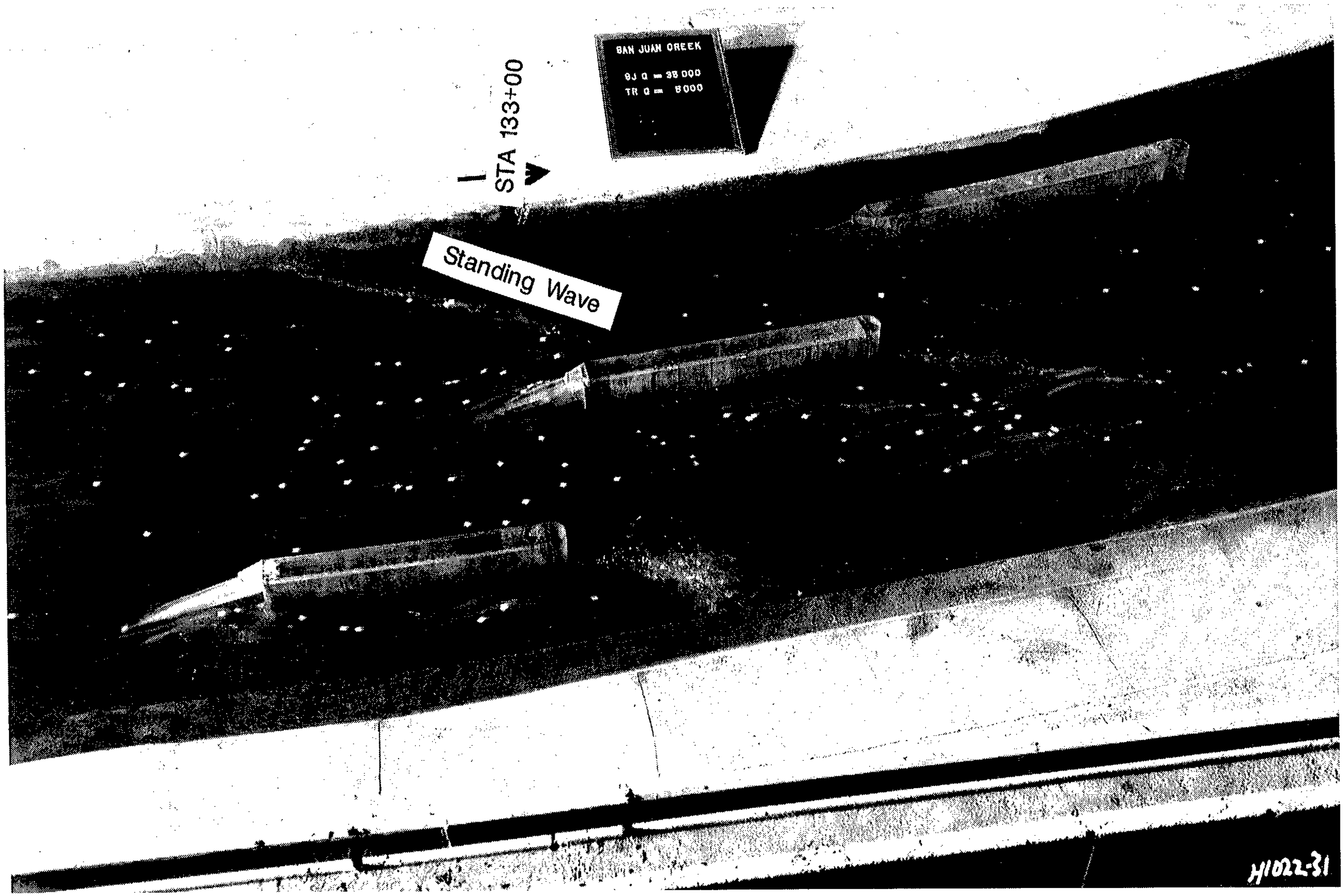
c. Balanced discharge, Q_{sj} 17,000 cfs (476 cu m/sec)

Photo 10. (Sheet 3 of 3)



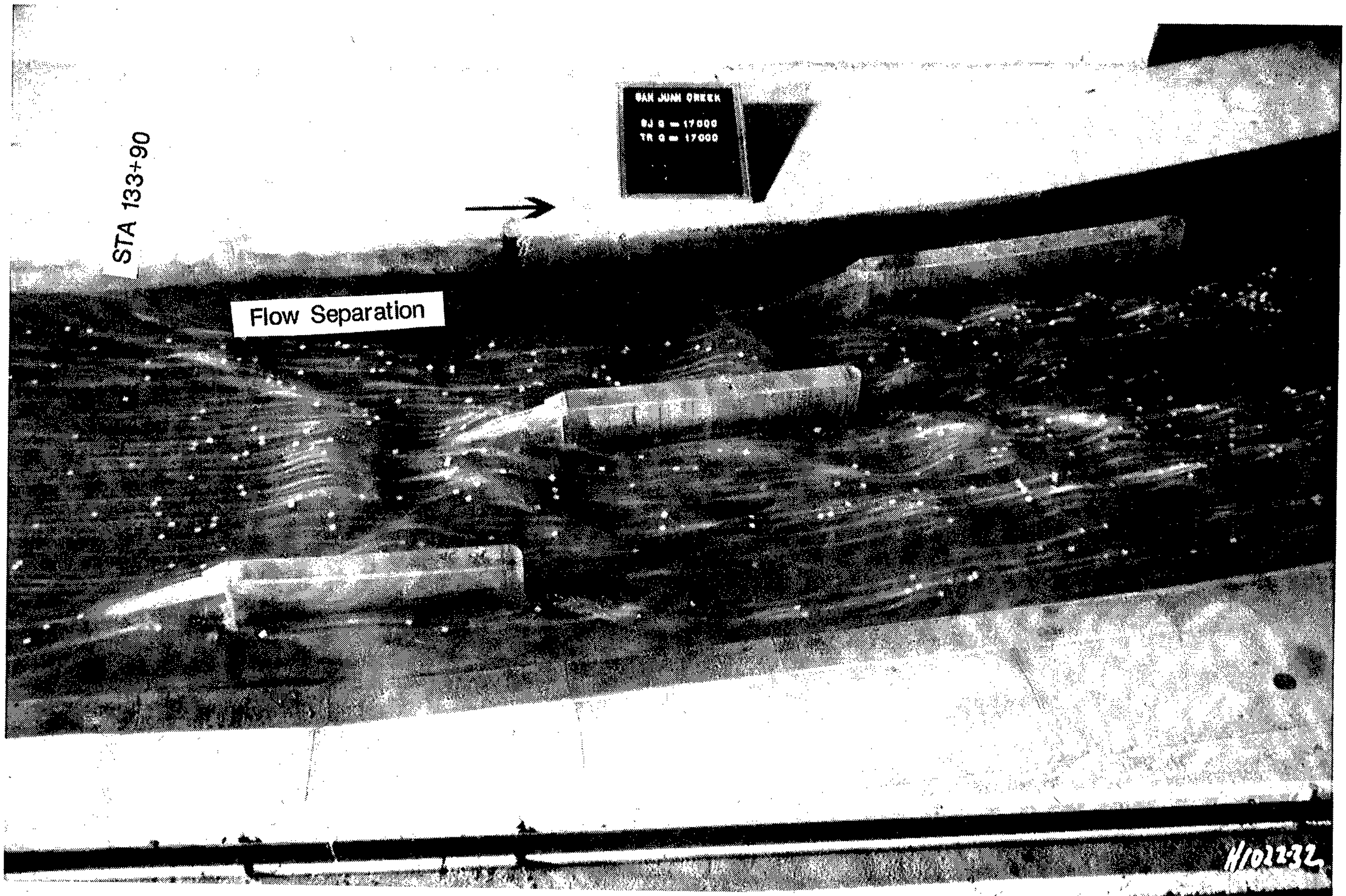
a. Design discharge, Q_{sj} 42,000 cfs (1,176 cu m/sec)

Photo 11. San Juan Creek, type 7 design, flow conditions in the vicinity of the railroad bridge piers, side view. Flow separation observed on left bank created the standing wave near the center railroad bridge pier. Depth of flow increased at nose of bridge piers and then decreased. (Sheet 1 of 3)



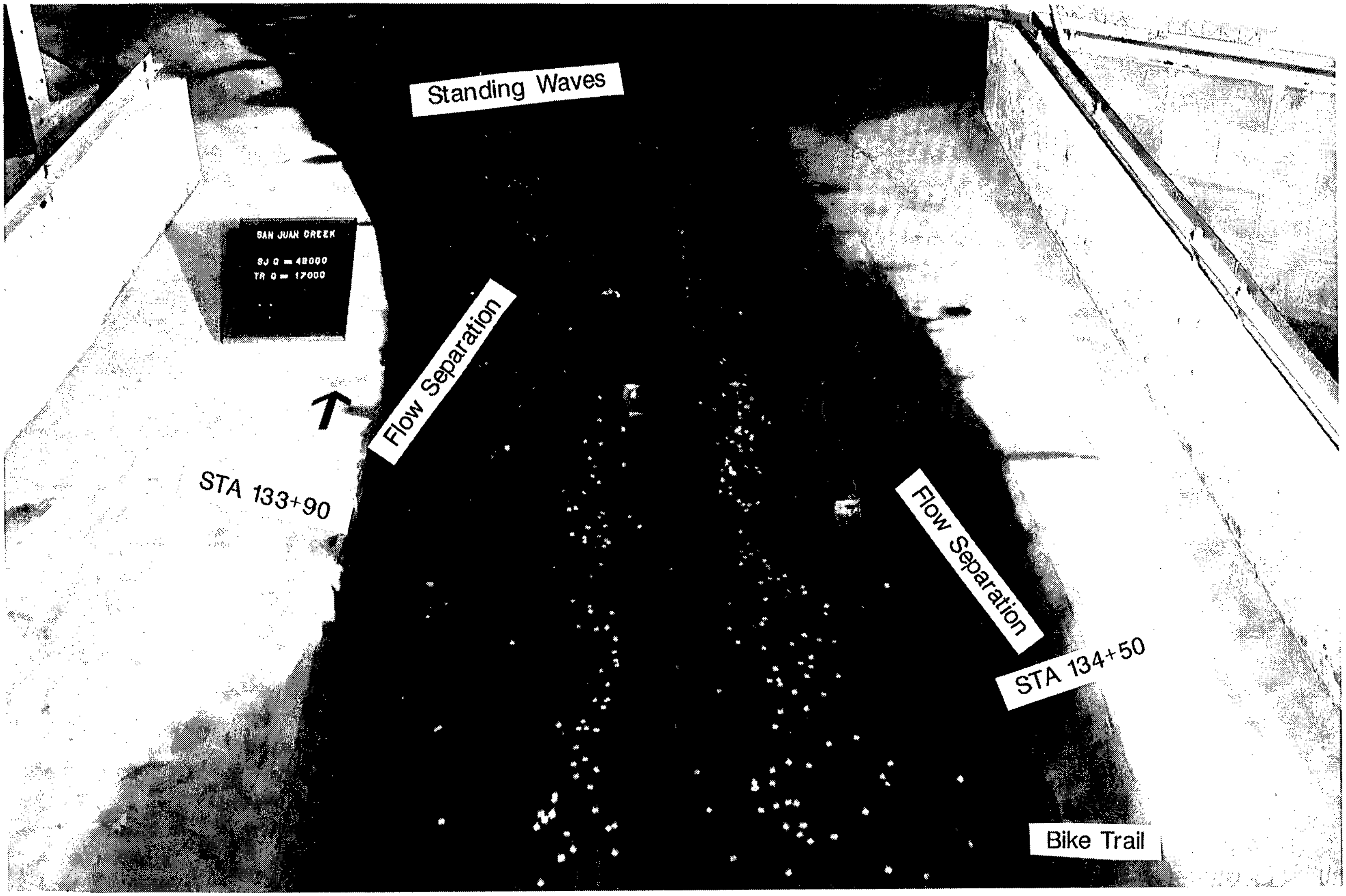
b. Unbalanced discharge, Q_{sj} 35,000 cfs (980 cu m/sec)

Photo 11. (Sheet 2 of 3)



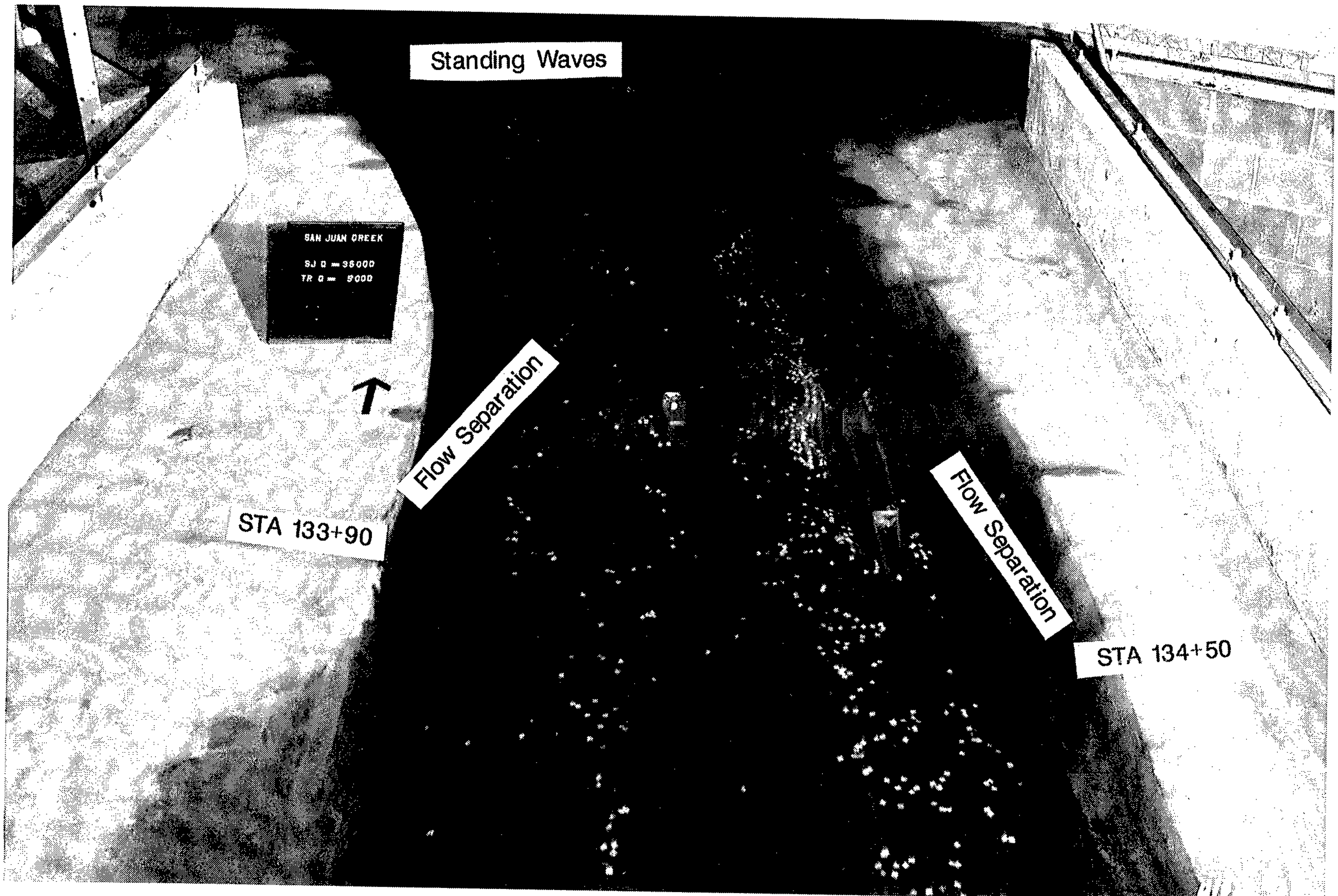
c. Balanced design, Q_{sj} 17,000 cfs (476 cu m/sec)

Photo 11. (Sheet 3 of 3)



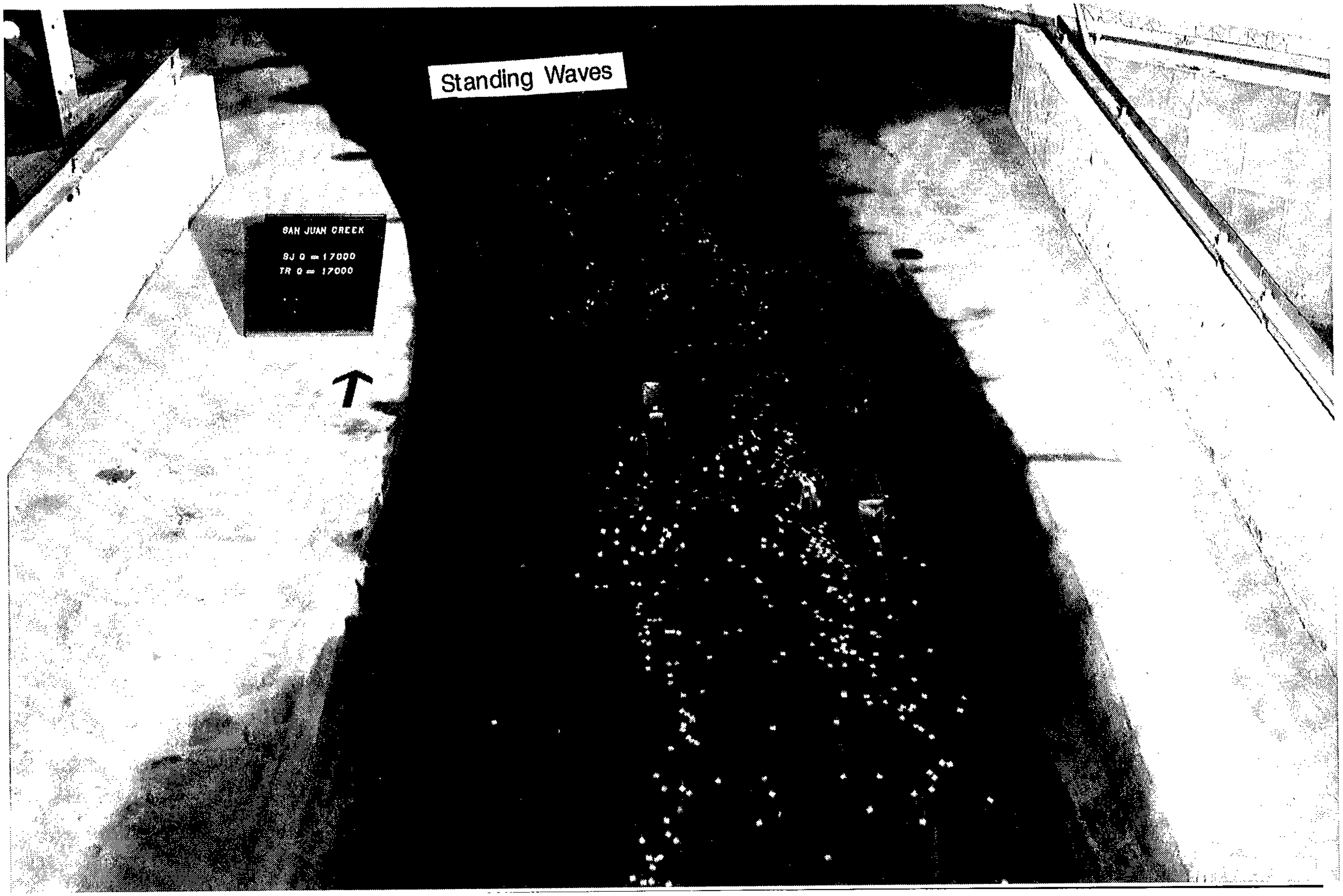
a. Design discharge, Q_{sj} 42,000 cfs (1,176 cu m/sec)

Photo 12. San Juan Creek, type 7 design, flow conditions in the vicinity of the railroad bridge piers, downstream view. Flow separation observed on left bank, created by the side slope transition to a vertical wall, and right bank, created by the bike trail, contributed to standing waves observed. (Sheet 1 of 3)



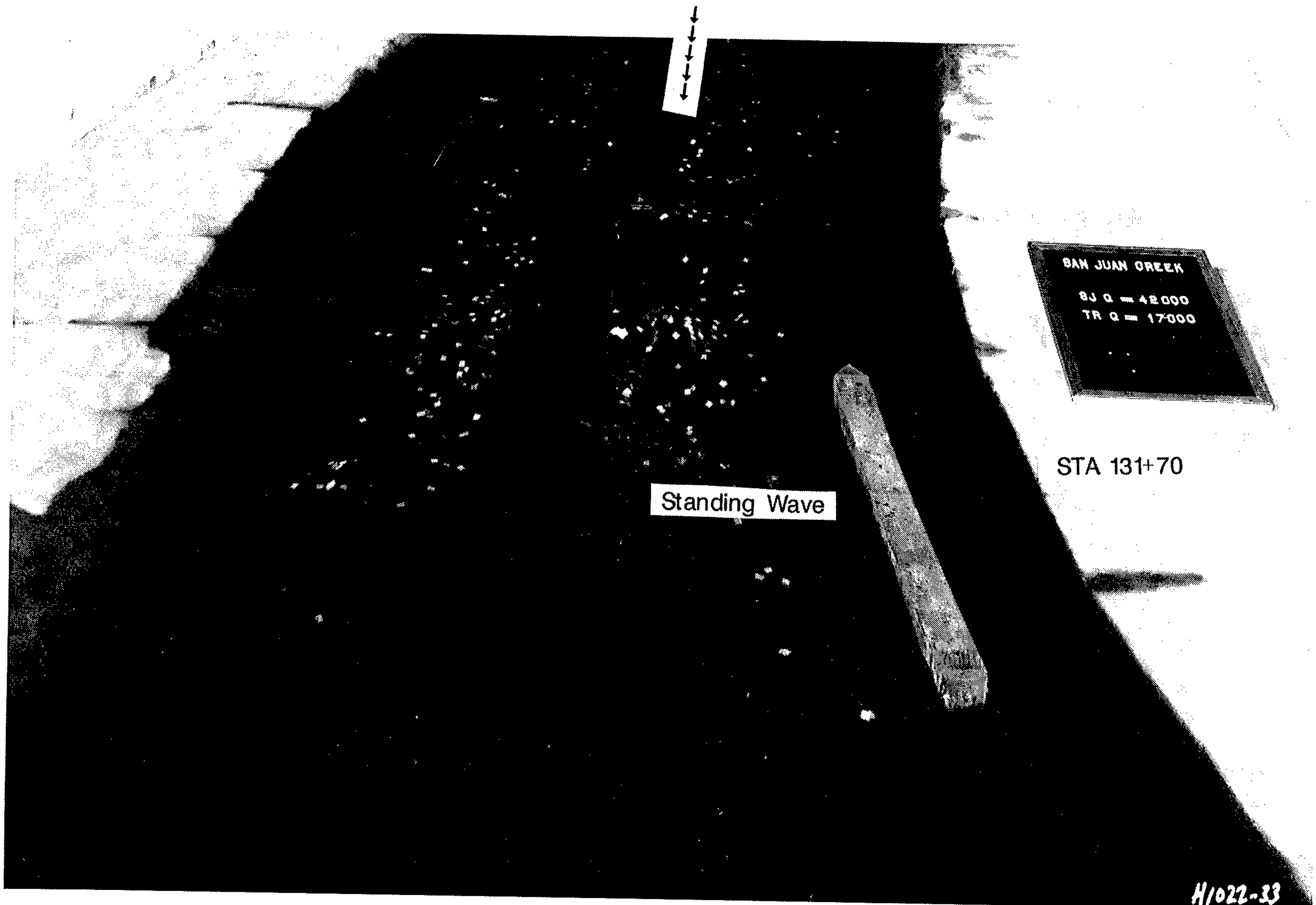
b. Unbalanced discharge, Q_{sj} 35,000 cfs (980 cu m/sec)

Photo 12. (Sheet 2 of 3)



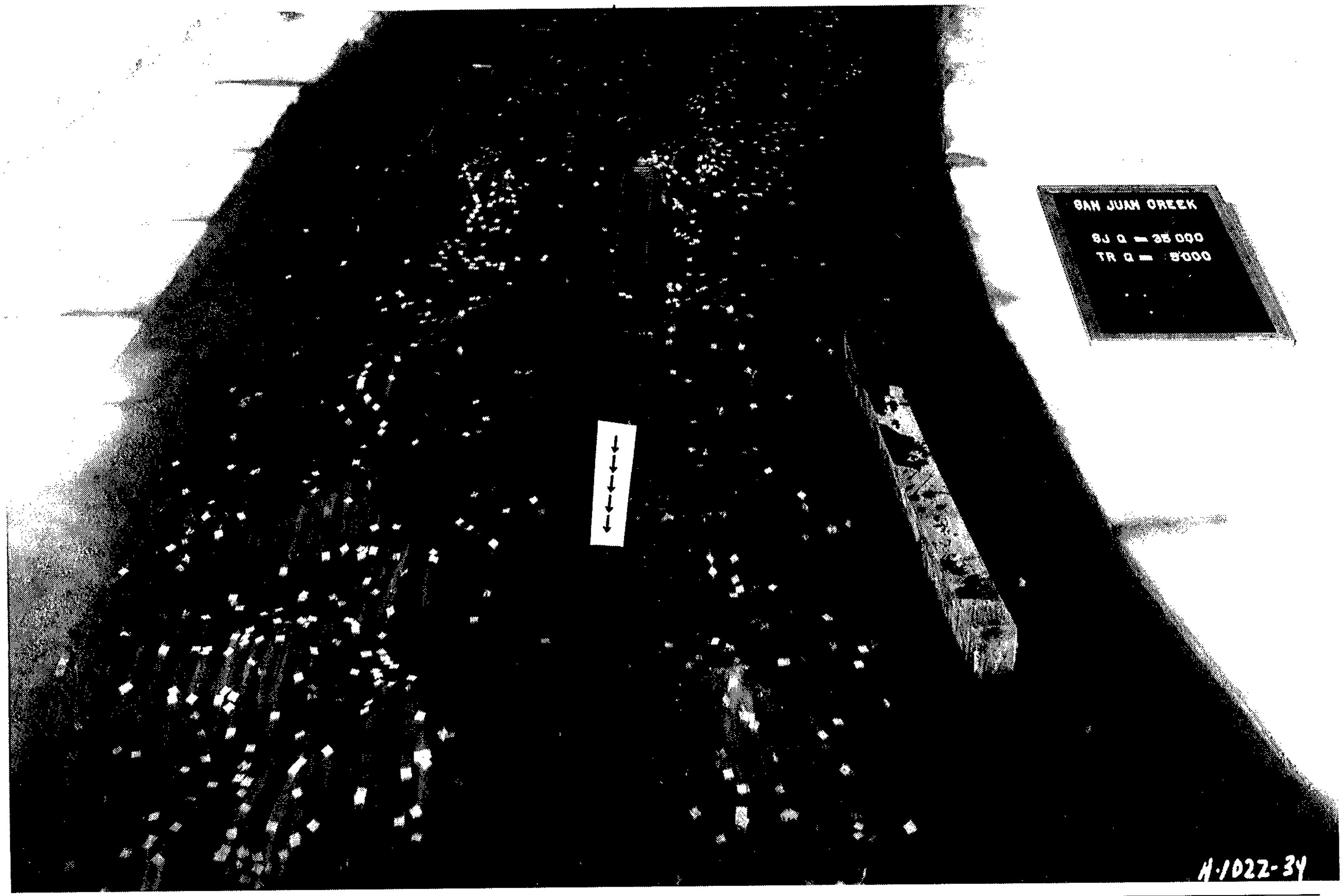
c. Balanced discharge, Q_{sj} 17,000 cfs (476 cu m/sec)

Photo 12. (Sheet 3 of 3)



a. Design discharge, Q_{sj} 42,000 cfs (1,176 cu m/sec)

Photo 13. San Juan Creek, type 7 design, flow conditions in the vicinity of the railroad bridge piers, upstream view. Oblique standing wave observed between center and left piers. Standing waves observed downstream of the railroad bridge. Flow separation on right and left banks forced flow to concentrate in center of channel. (Sheet 1 of 3)



b. Unbalanced discharge, Q_{sj} 35,000 cfs (980 cu m/sec)

Photo 13. (Sheet 2 of 3)

c. Balanced discharge, Q_{sj} 17,000 cfs (476 cu m/sec)

Photo 13. (Sheet 3 of 3)

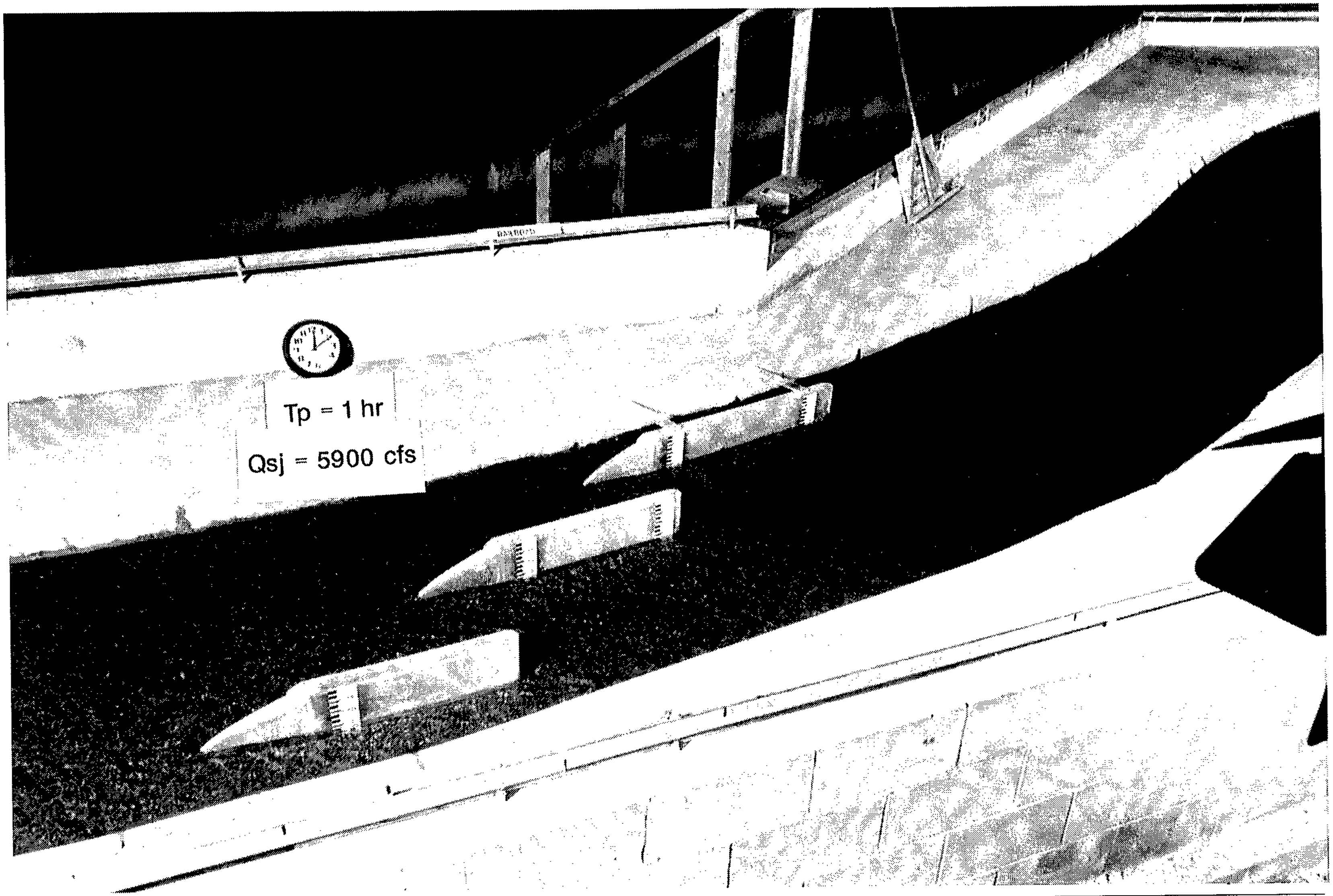


Photo 14. San Juan Creek, type 7 design, flow conditions in the vicinity of the railroad bridge piers during 24-hour storm hydrograph, side view, prototype time 1 hour, Q_{sj} 5,900 cfs (165 cu m/sec)

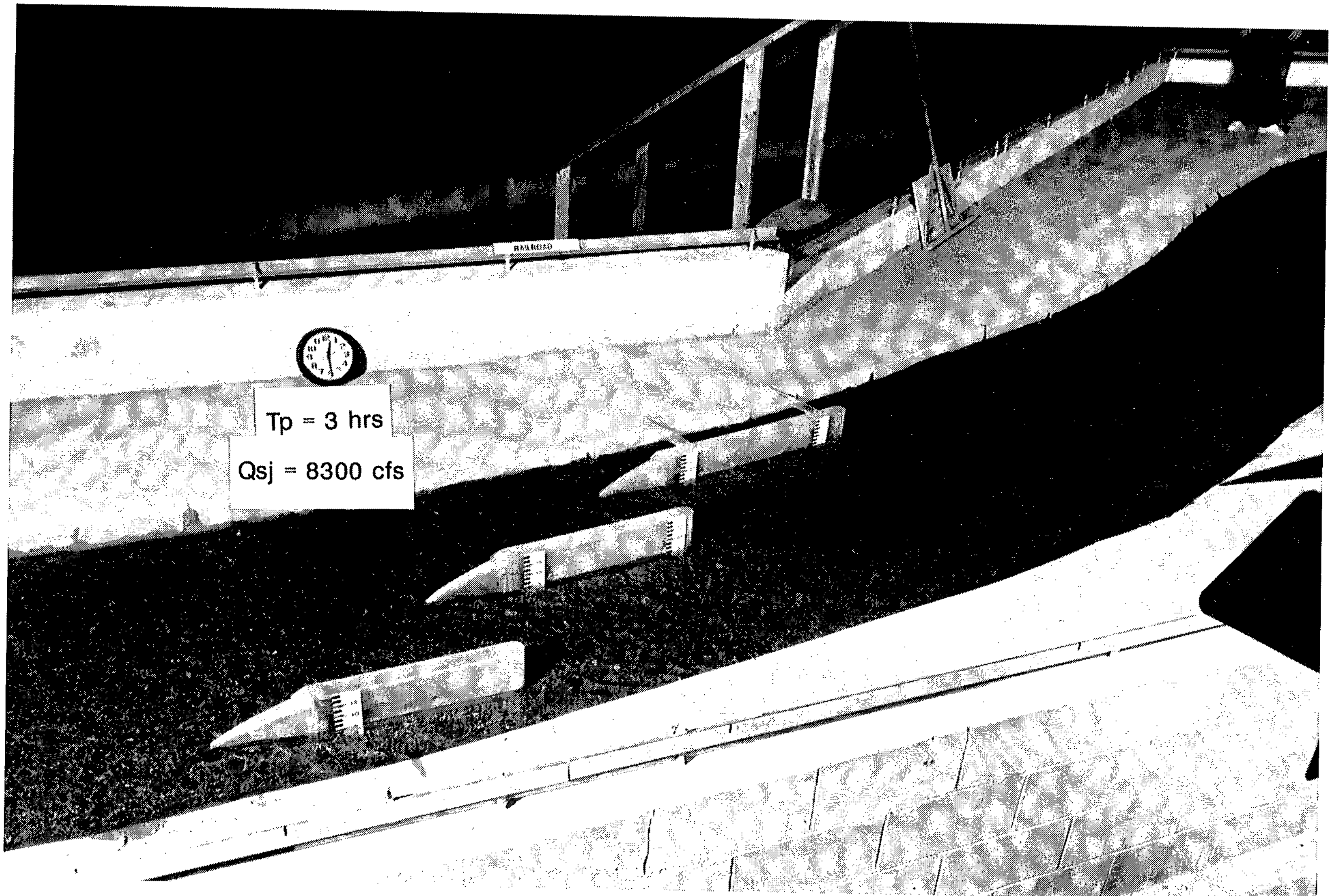


Photo 15. San Juan Creek, type 7 design, flow conditions in the vicinity of the railroad bridge piers during 24-hour storm hydrograph, side view, prototype time 3 hours, Q_{sj} 8,300 cfs (232 cu m/sec)

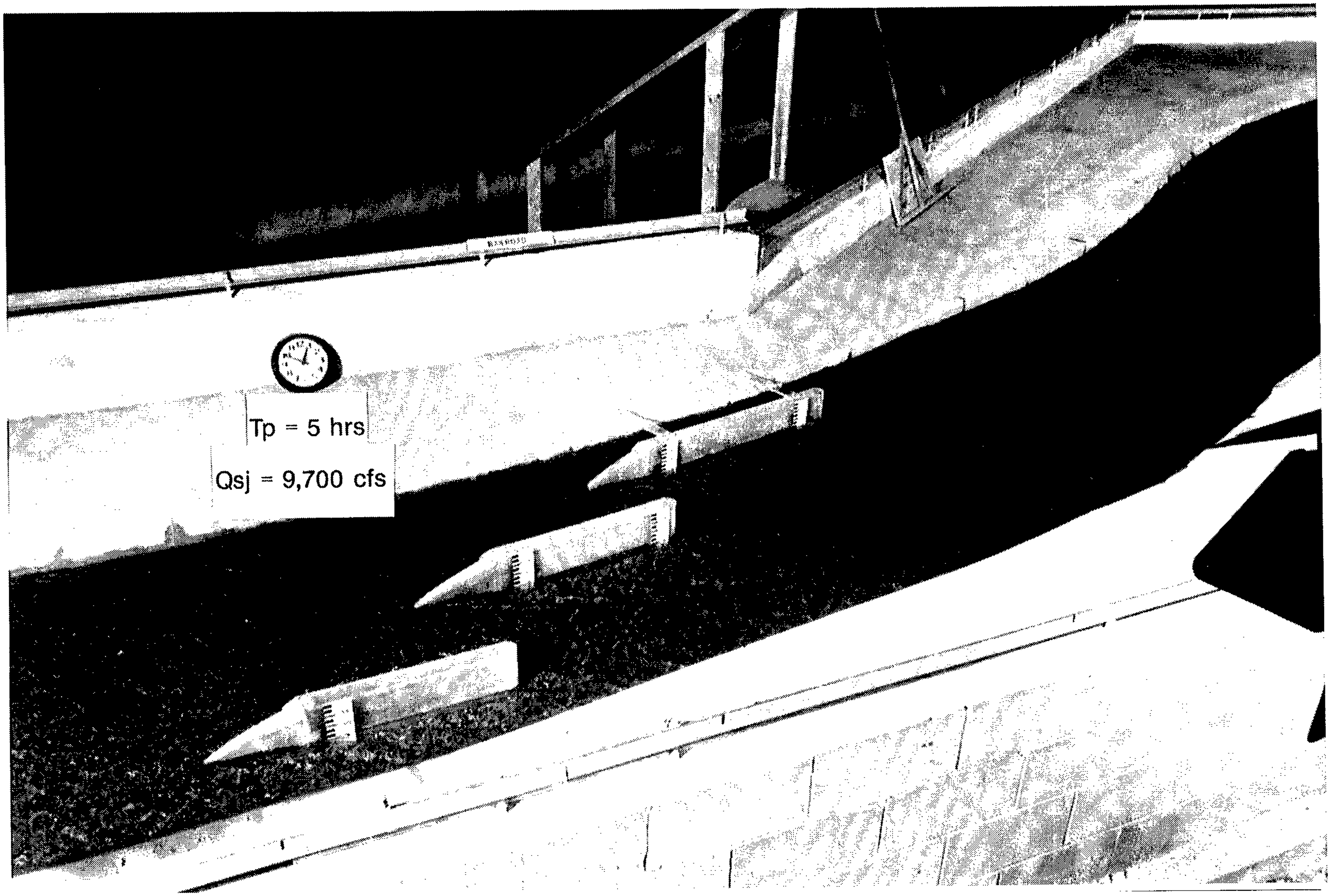


Photo 16. San Juan Creek, type 7 design, flow conditions in the vicinity of the railroad bridge piers during 24-hour storm hydrograph, side view, prototype time 5 hours, Q_{sj} 9,700 cfs (272 cu m/sec)

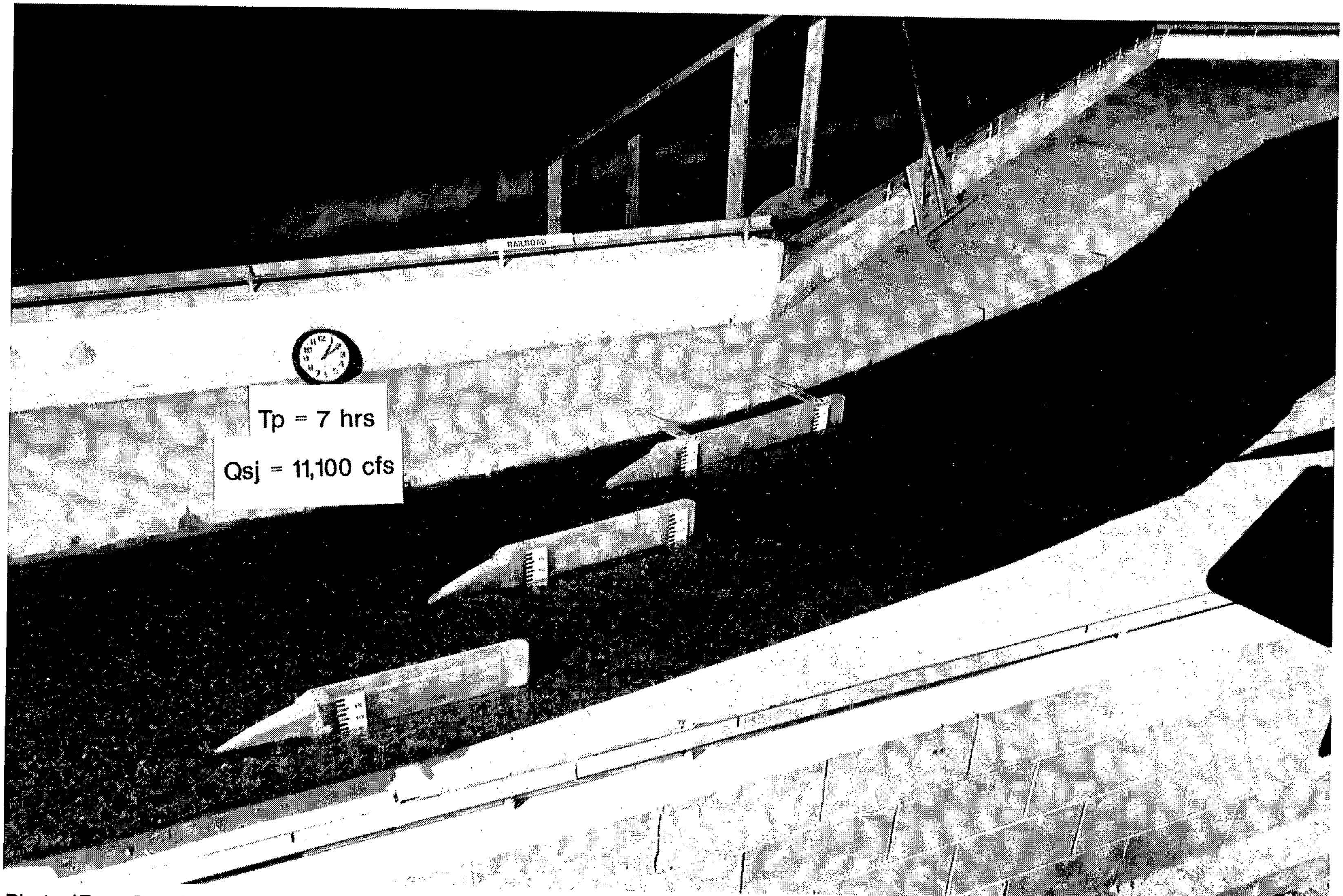


Photo 17. San Juan Creek, type 7 design, flow conditions in the vicinity of the railroad bridge piers during 24-hour storm hydrograph, side view, prototype time 7 hours, Q_{sj} 11,100 cfs (311 cu m/sec)

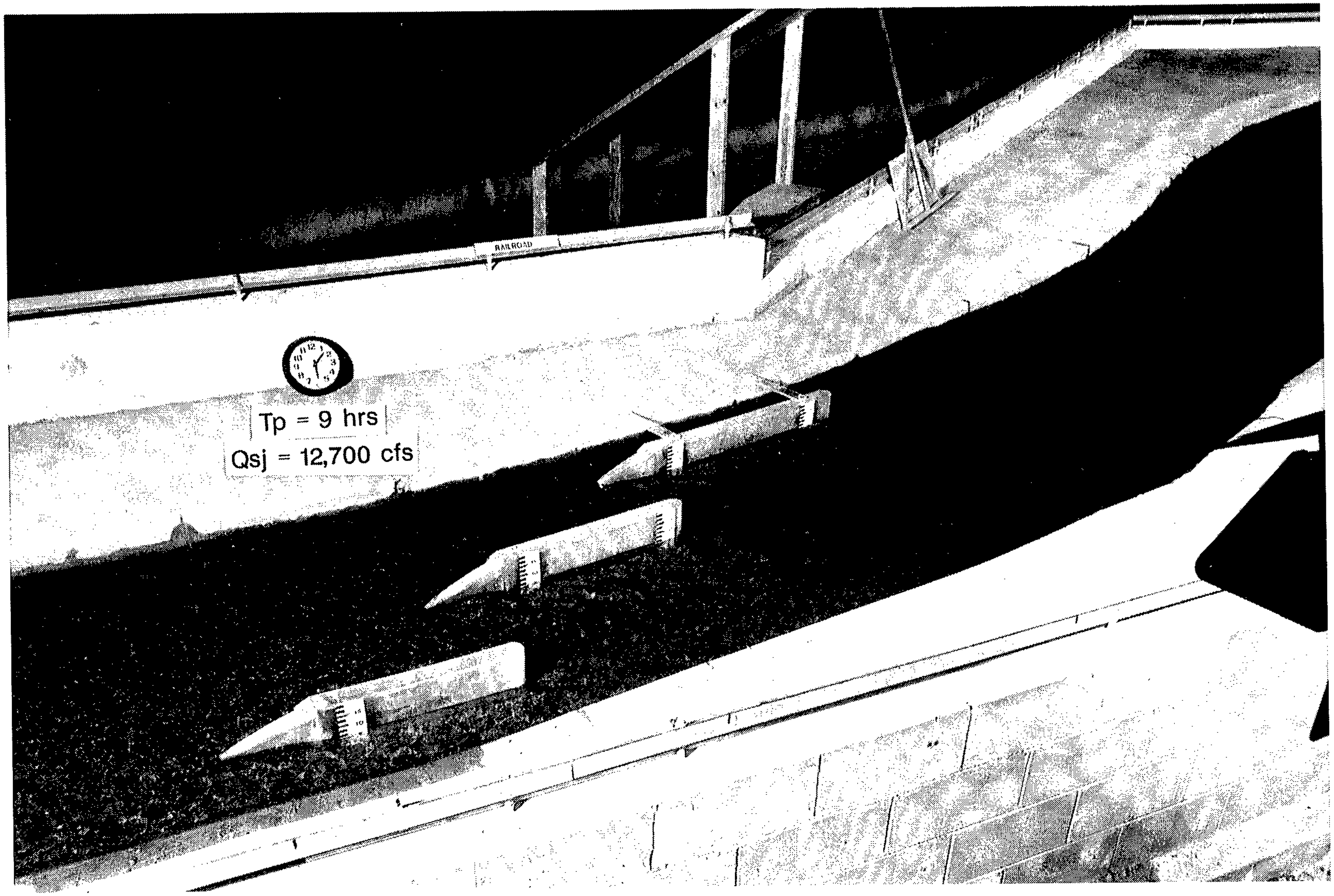


Photo 18. San Juan Creek, type 7 design, flow conditions in the vicinity of the railroad bridge piers during 24-hour storm hydrograph, side view, prototype time 9 hours, Q_{sj} 12,700 cfs (356 cu m/sec)

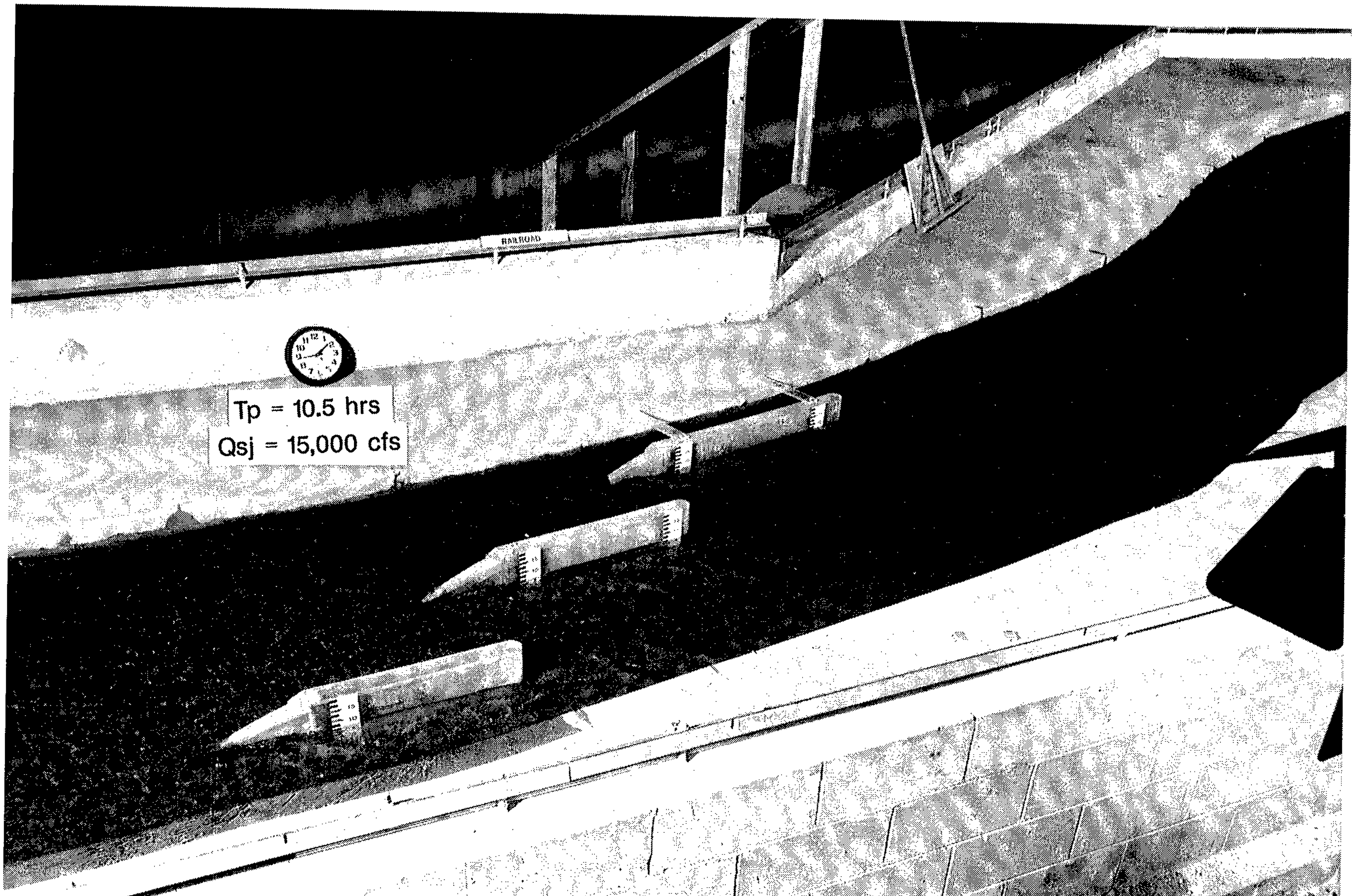


Photo 19. San Juan Creek, type 7 design, flow conditions in the vicinity of the railroad bridge piers during 24-hour storm hydrograph, side view, prototype time 10.5 hours, Q_{sj} 15,000 cfs (420 cu m/sec)

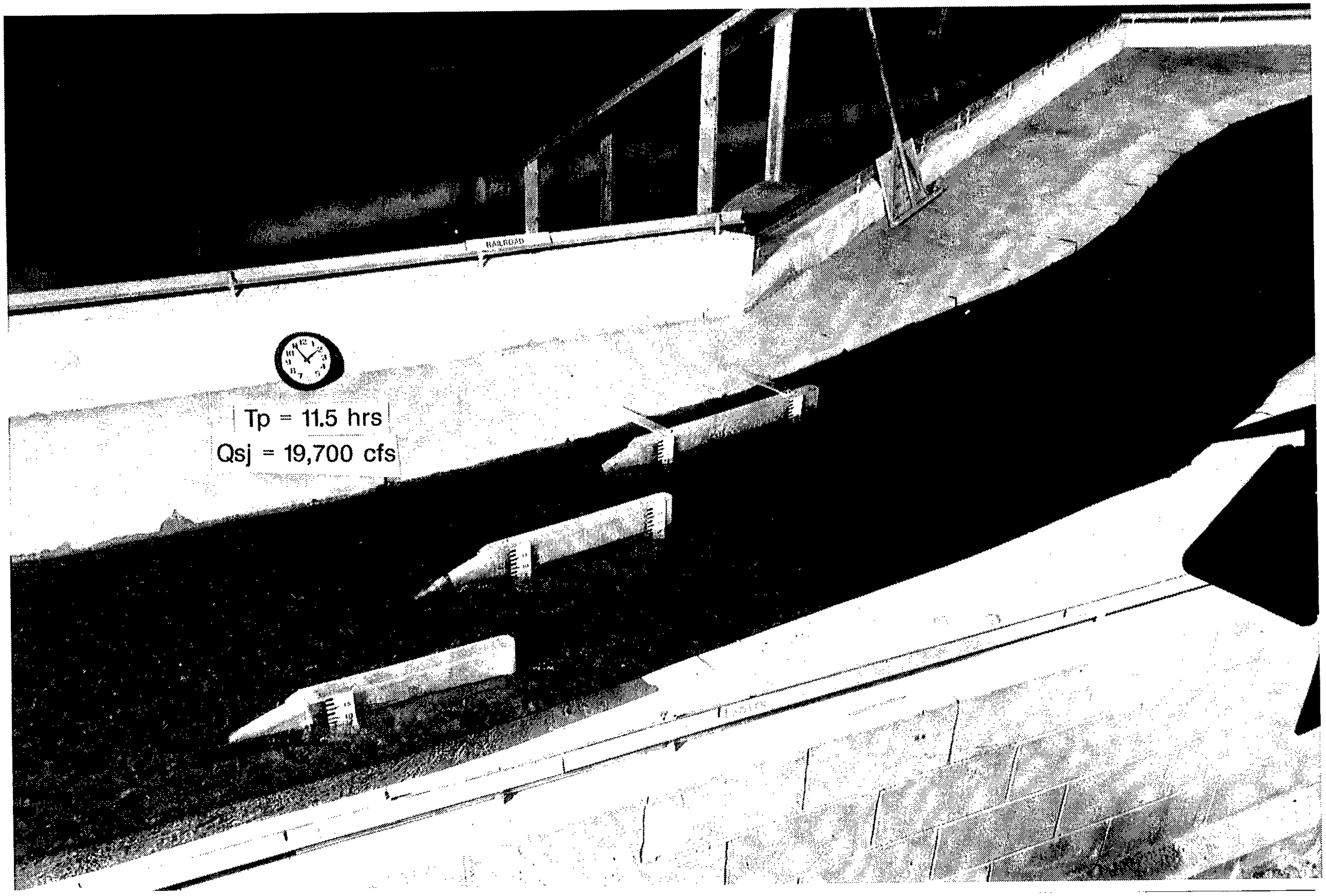


Photo 20. San Juan Creek, type 7 design, flow conditions in the vicinity of the railroad bridge piers during 24-hour storm hydrograph, side view, prototype time 11.5 hours, Q_{sj} 19,700 cfs (552 cu m/sec)

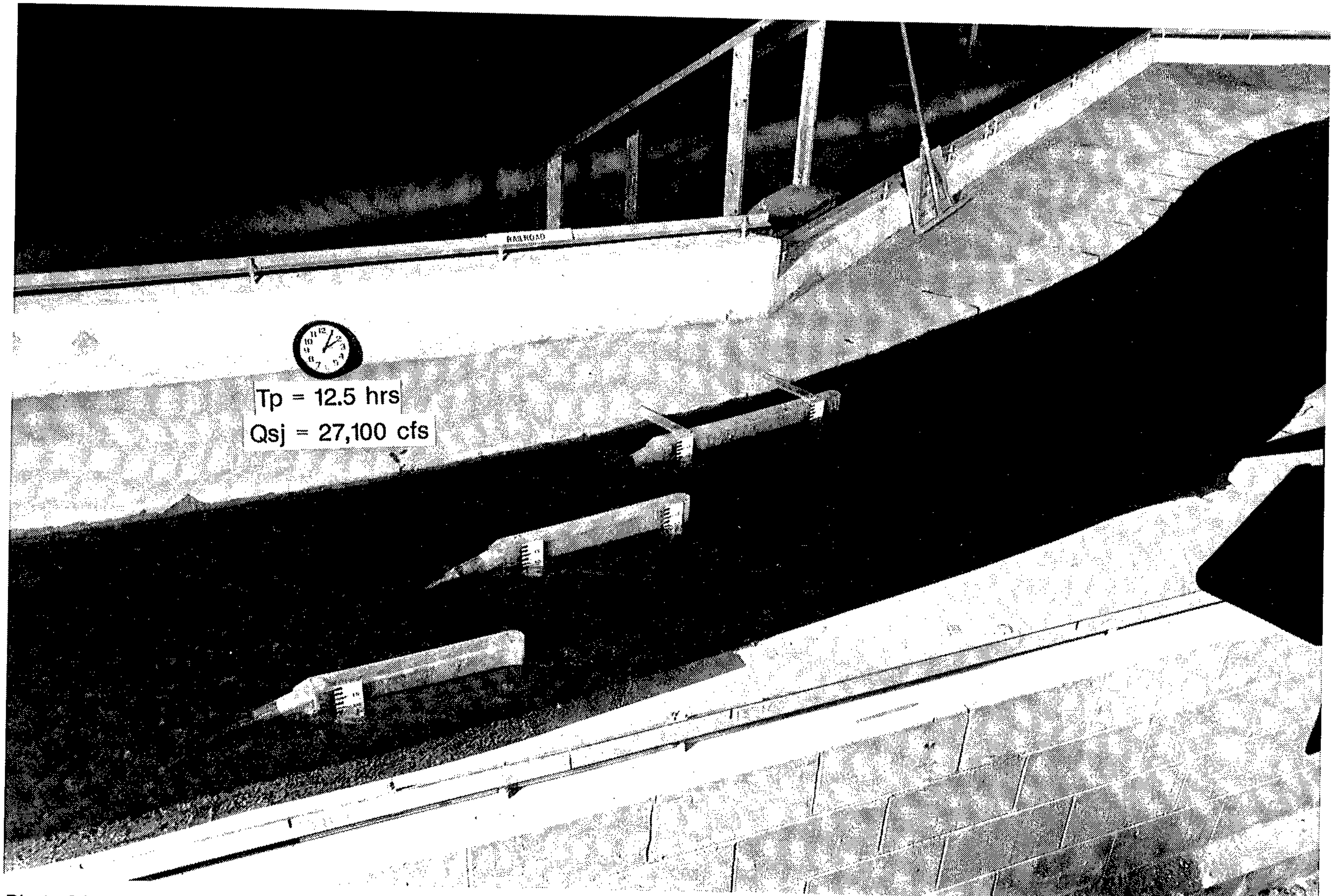


Photo 21. San Juan Creek, type 7 design, flow conditions in the vicinity of the railroad bridge piers during 24-hour storm hydrograph, side view, prototype time 12.5 hours, Q_{sj} 27,100 cfs (759 cu m/sec)

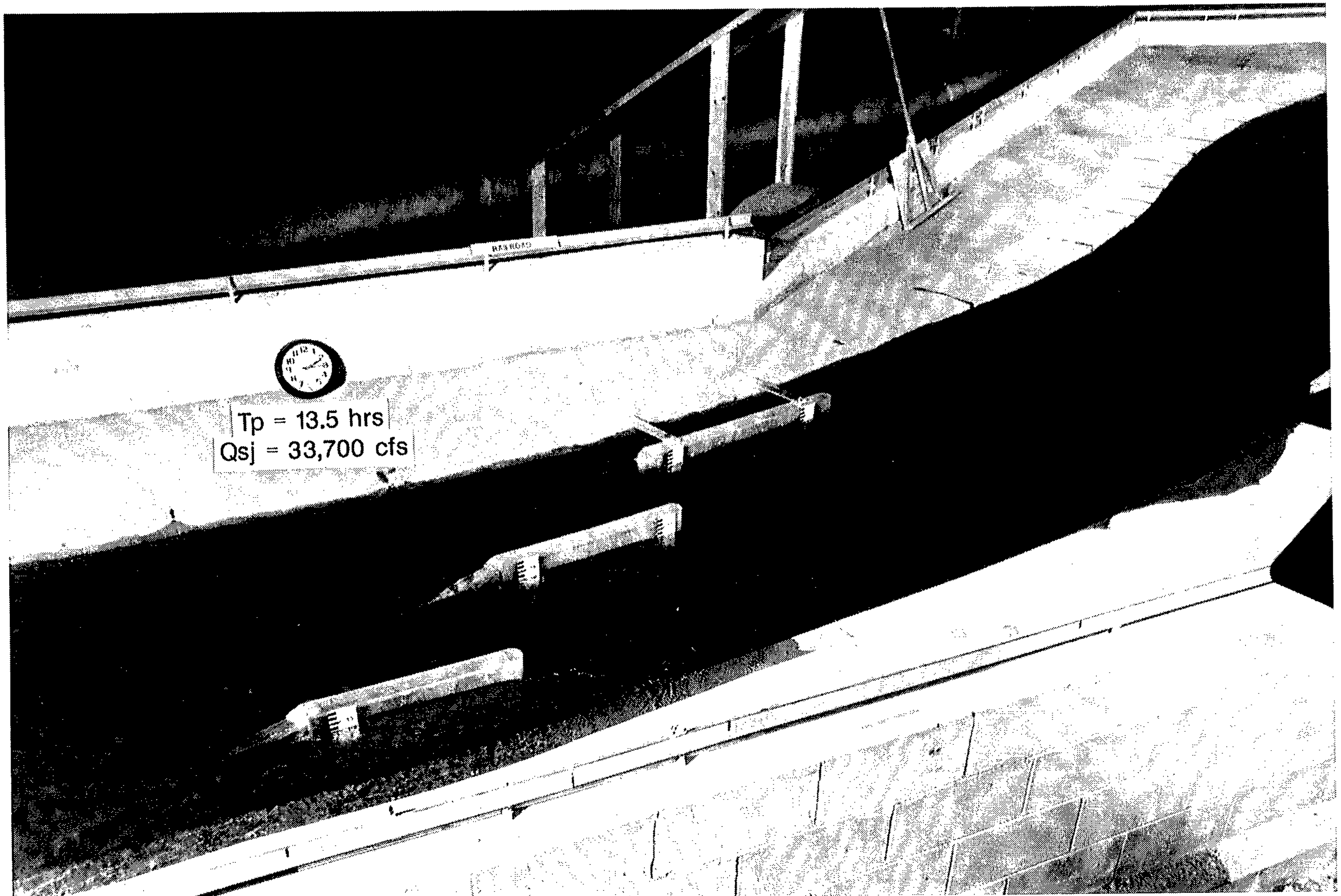


Photo 22. San Juan Creek, type 7 design, flow conditions in the vicinity of the railroad bridge piers during 24-hour storm hydrograph, side view, prototype time 13.5 hours, Q_{sj} 33,700 cfs (944 cu m/sec)

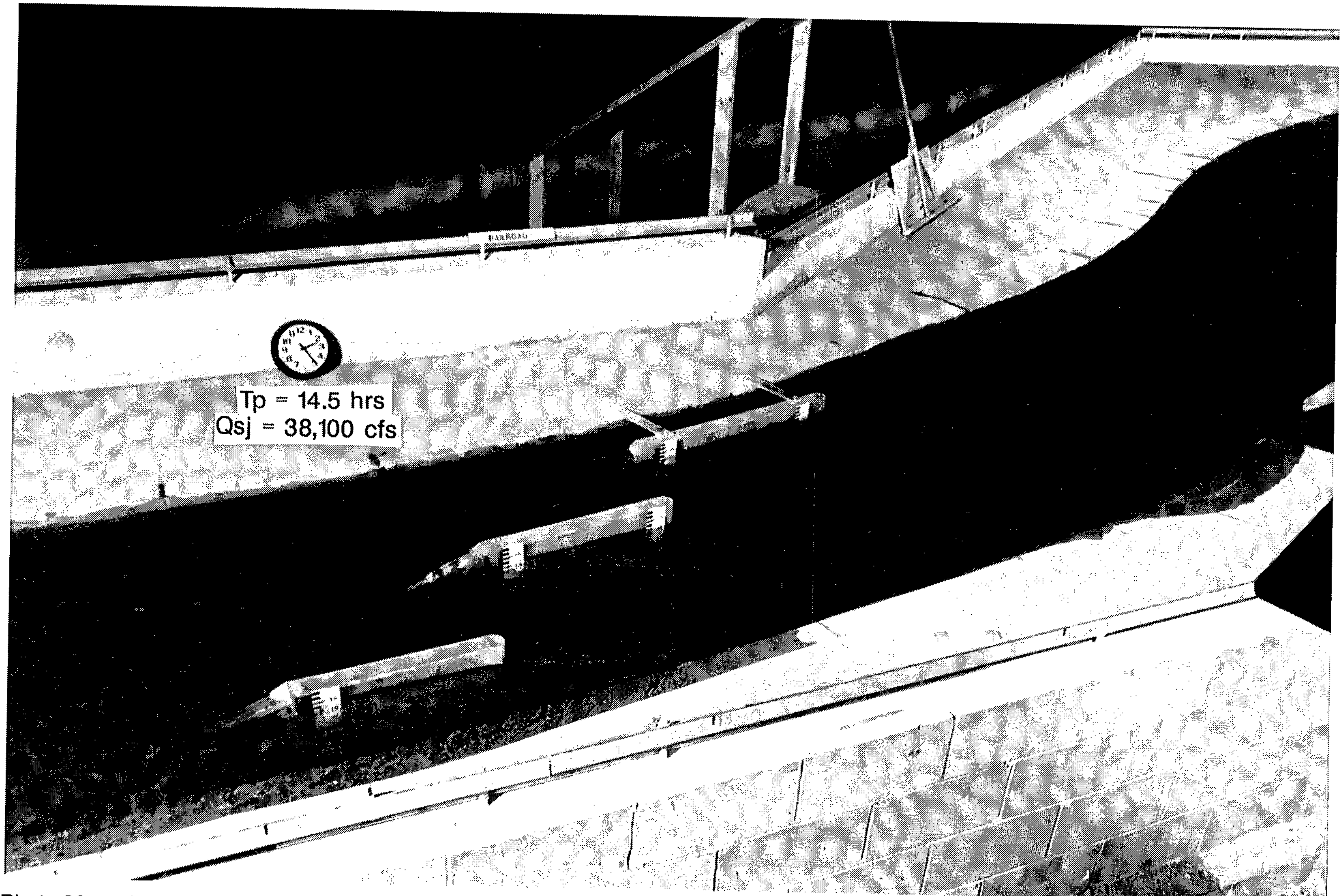


Photo 23. San Juan Creek, type 7 design, flow conditions in the vicinity of the railroad bridge piers during 24-hour storm hydrograph, side view, prototype time 14.5 hours, Q_{sj} 38,100 cfs (1,067 cu m/sec)

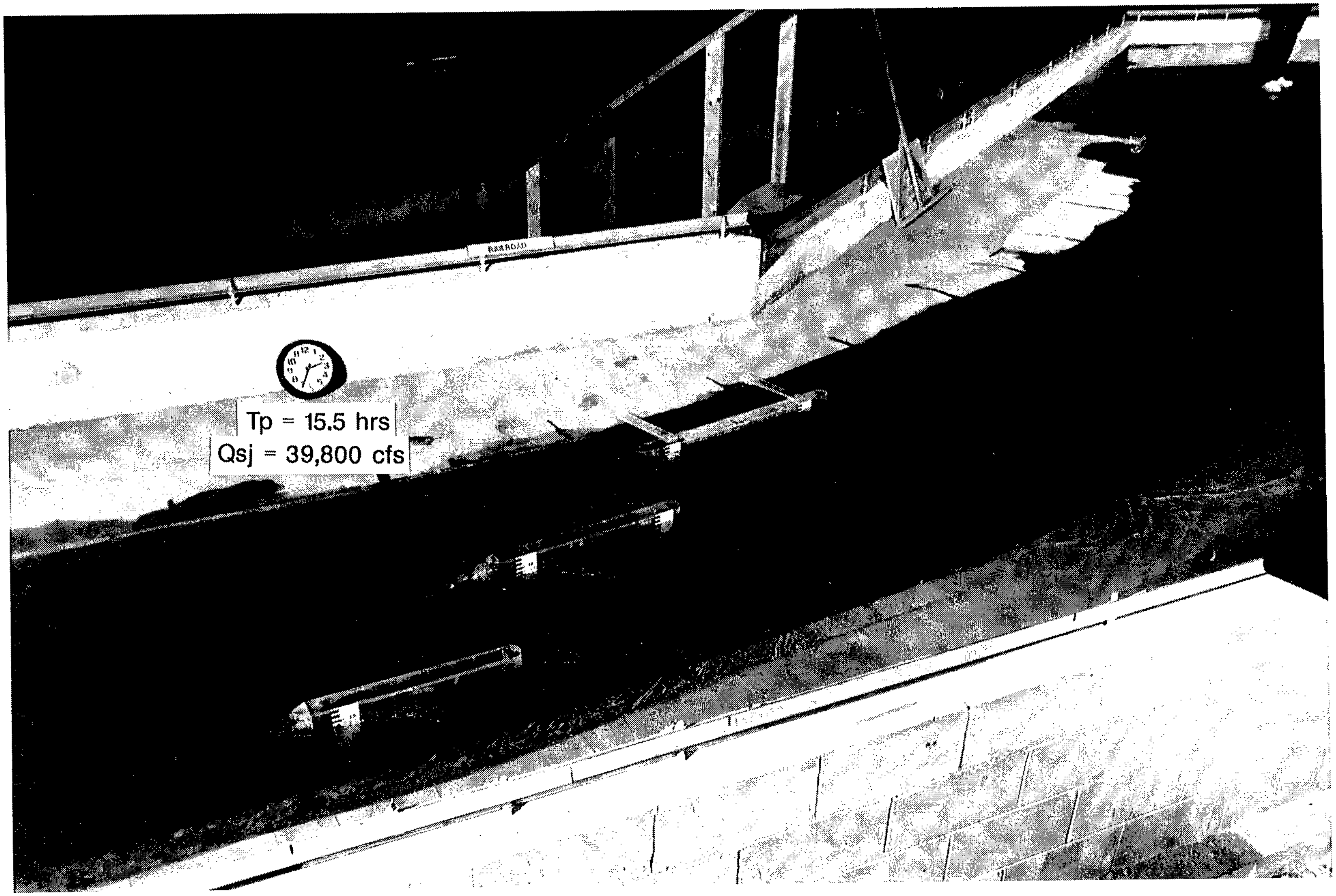


Photo 24. San Juan Creek, type 7 design, flow conditions in the vicinity of the railroad bridge piers during 24-hour storm hydrograph, side view, prototype time 15.5 hours, Q_{sj} 39,800 cfs (1,114 cu m/sec)

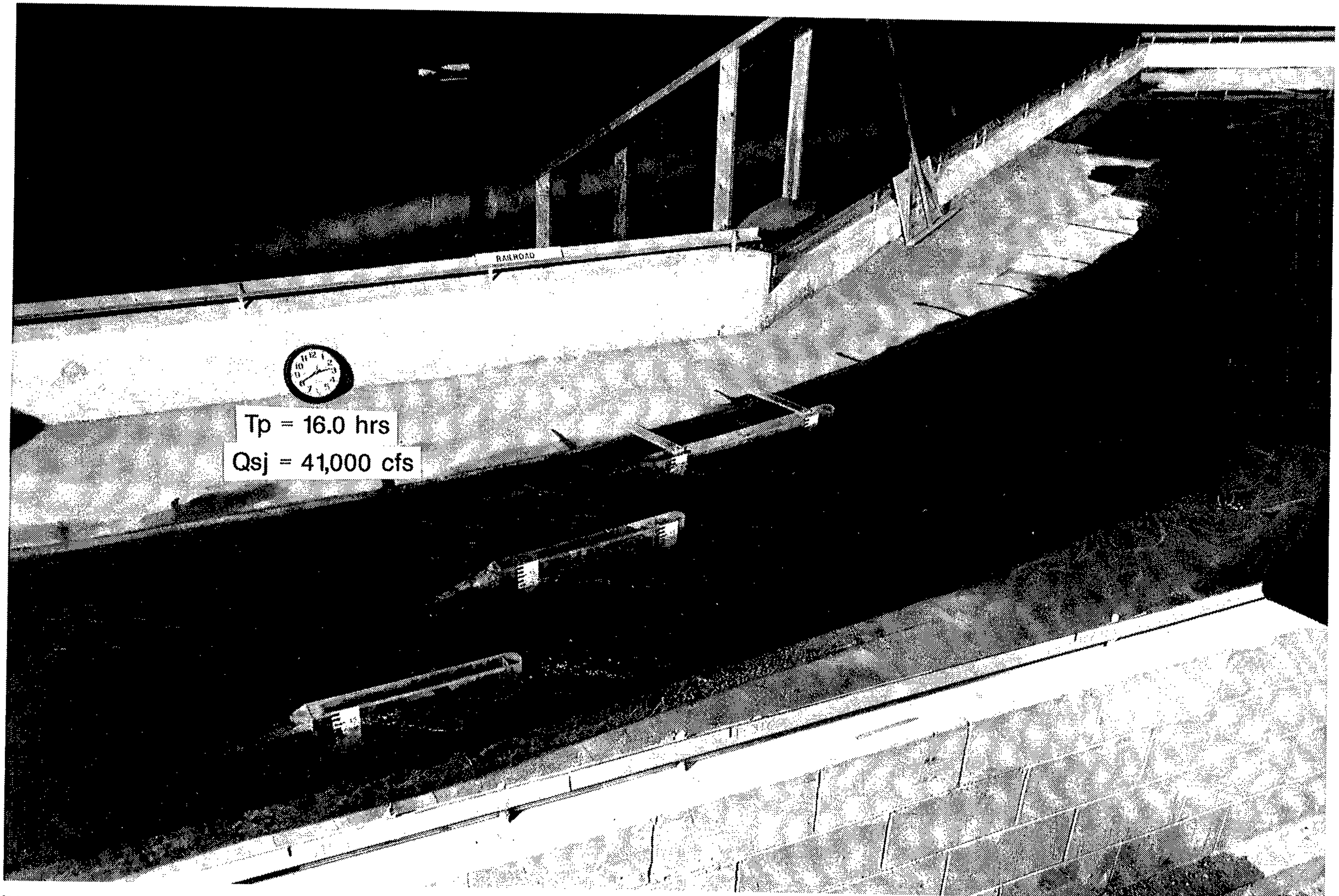


Photo 25. San Juan Creek, type 7 design, flow conditions in the vicinity of the railroad bridge piers during 24-hour storm hydrograph, side view, prototype time 16 hours, Q_{sj} 41,000 cfs (1,148 cu m/sec)

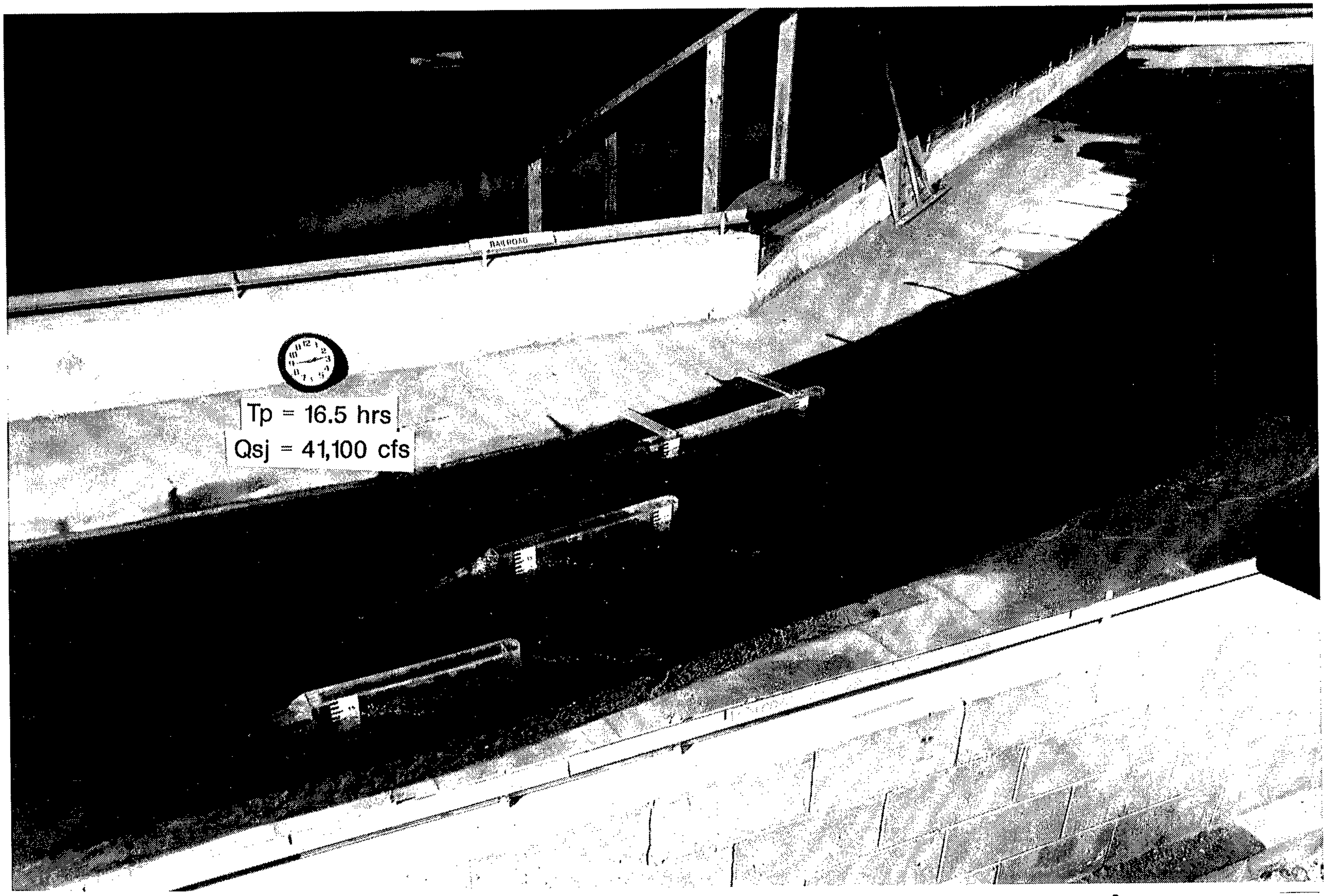


Photo 26. San Juan Creek, type 7 design, flow conditions in the vicinity of the railroad bridge piers during 24-hour storm hydrograph, side view, prototype time 16.5 hours, Q_{sj} 41,100 cfs (1,151 cu m/sec)

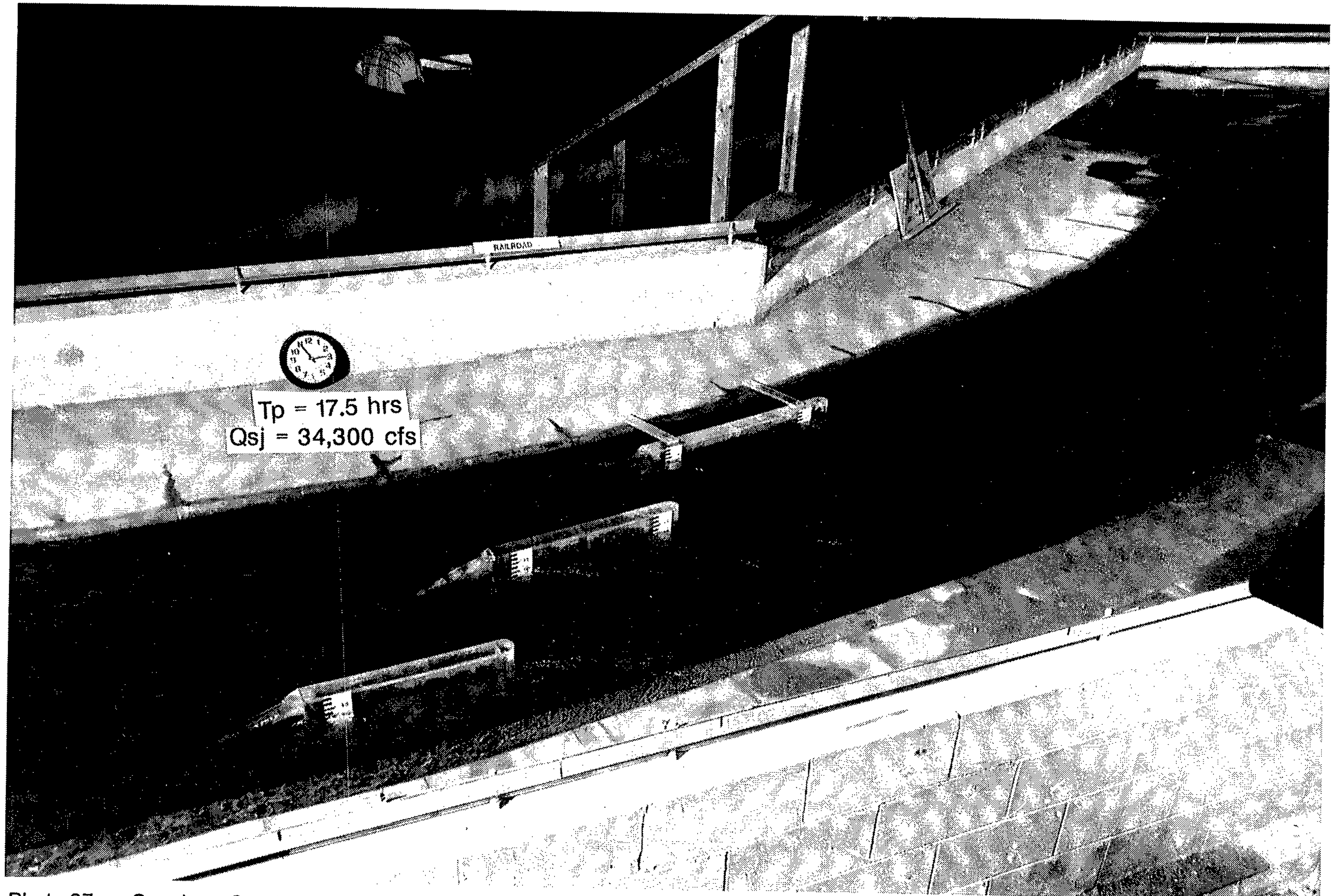


Photo 27. San Juan Creek, type 7 design, flow conditions in the vicinity of the railroad bridge piers during 24-hour storm hydrograph, side view, prototype time 17.5 hours, Q_{sj} 34,300 cfs (960 cu m/sec)

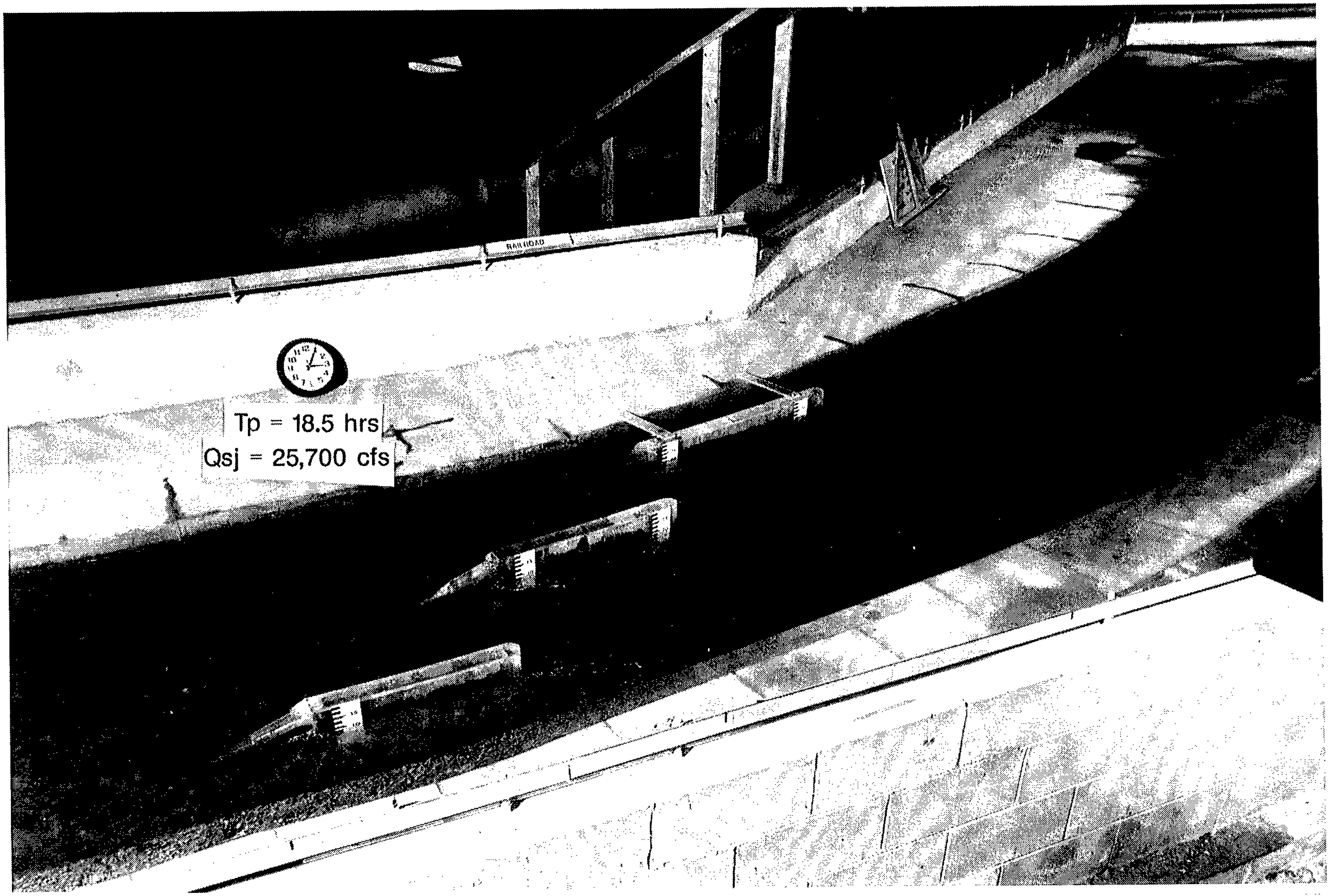


Photo 28. San Juan Creek, type 7 design, flow conditions in the vicinity of the railroad bridge piers during 24-hour storm hydrograph, side view, prototype time 18.5 hours, Q_{sj} 25,700 cfs (720 cu m/sec)

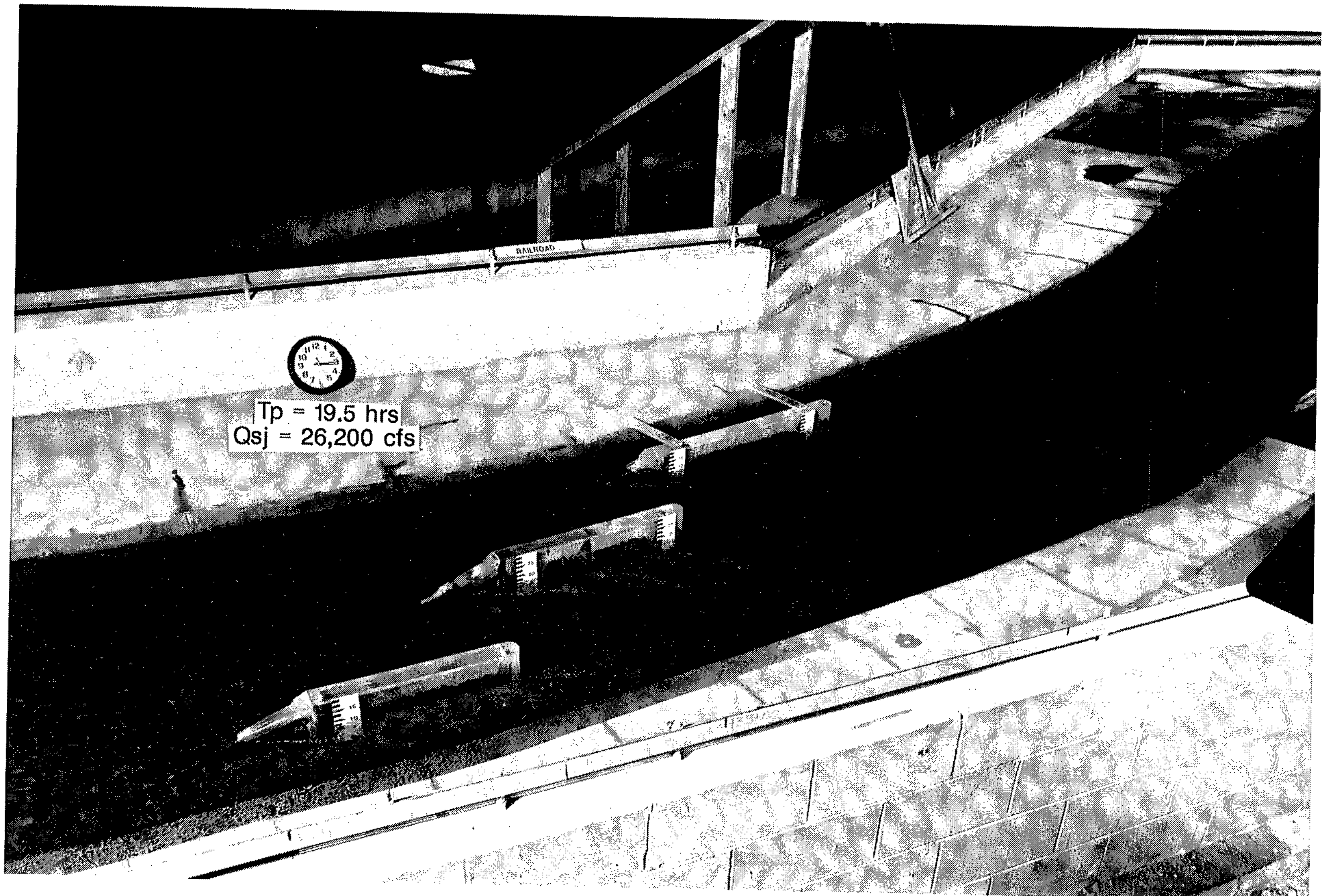


Photo 29. San Juan Creek, type 7 design, flow conditions in the vicinity of the railroad bridge piers during 24-hour storm hydrograph, side view, prototype time 19.5 hours, Q_{sj} 26,200 cfs (734 cu m/sec)

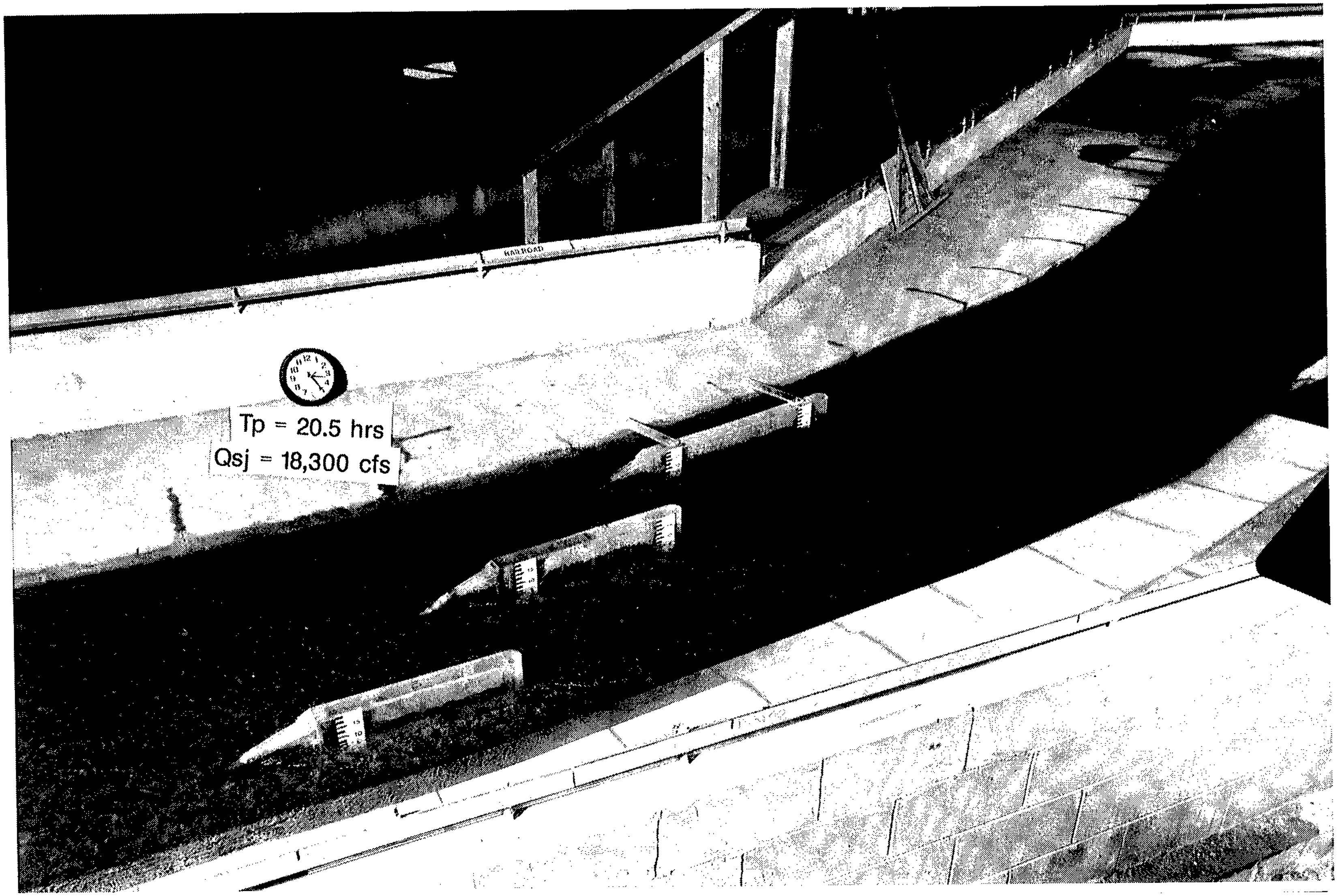


Photo 30. San Juan Creek, type 7 design, flow conditions in the vicinity of the railroad bridge piers during 24-hour storm hydrograph, side view, prototype time 20.5 hours, Q_{sj} 18,300 cfs (512 cu m/sec)

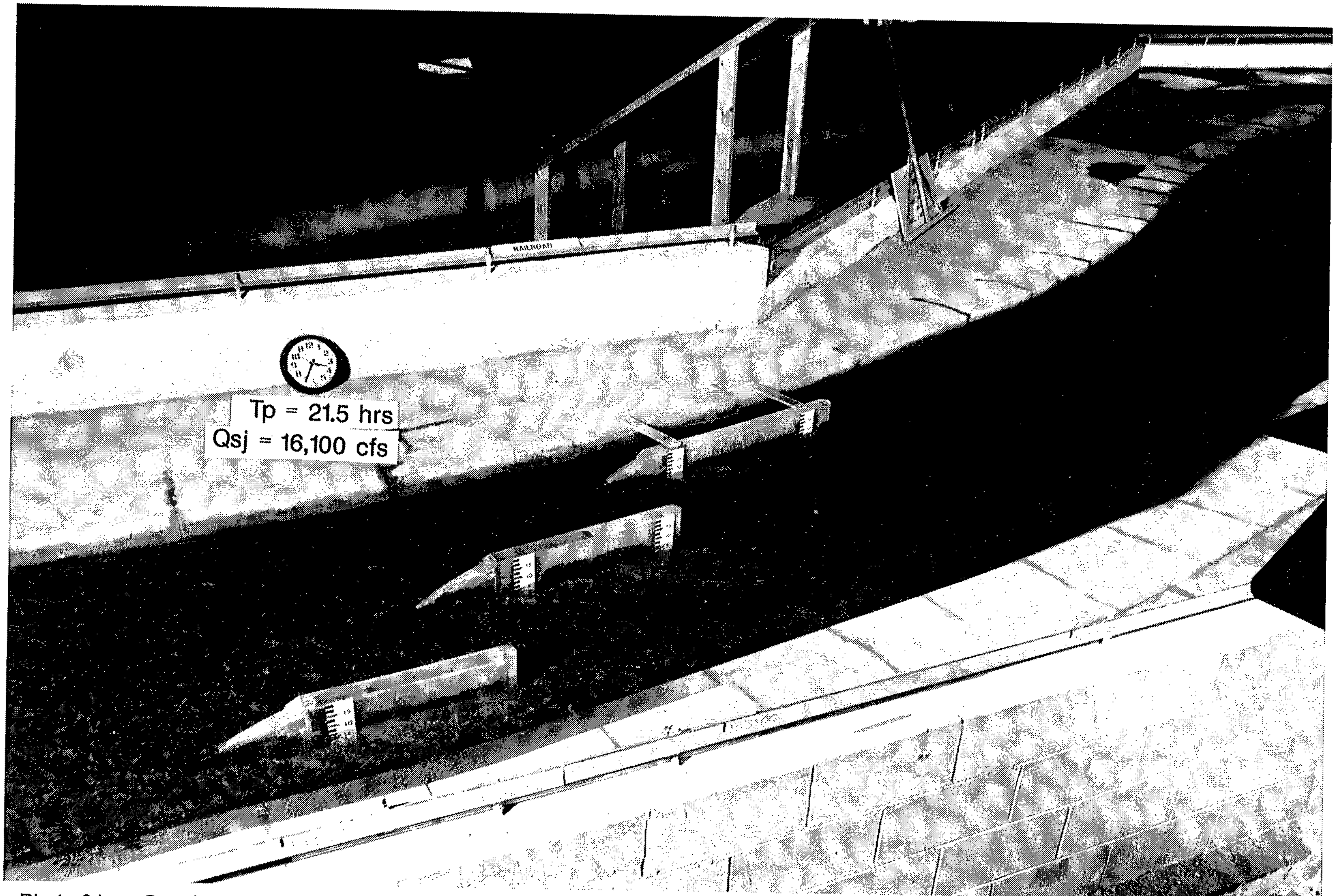


Photo 31. San Juan Creek, type 7 design, flow conditions in the vicinity of the railroad bridge piers during 24-hour storm hydrograph, side view, prototype time 21.5 hours, Q_{sj} 16,100 cfs (451 cu m/sec)

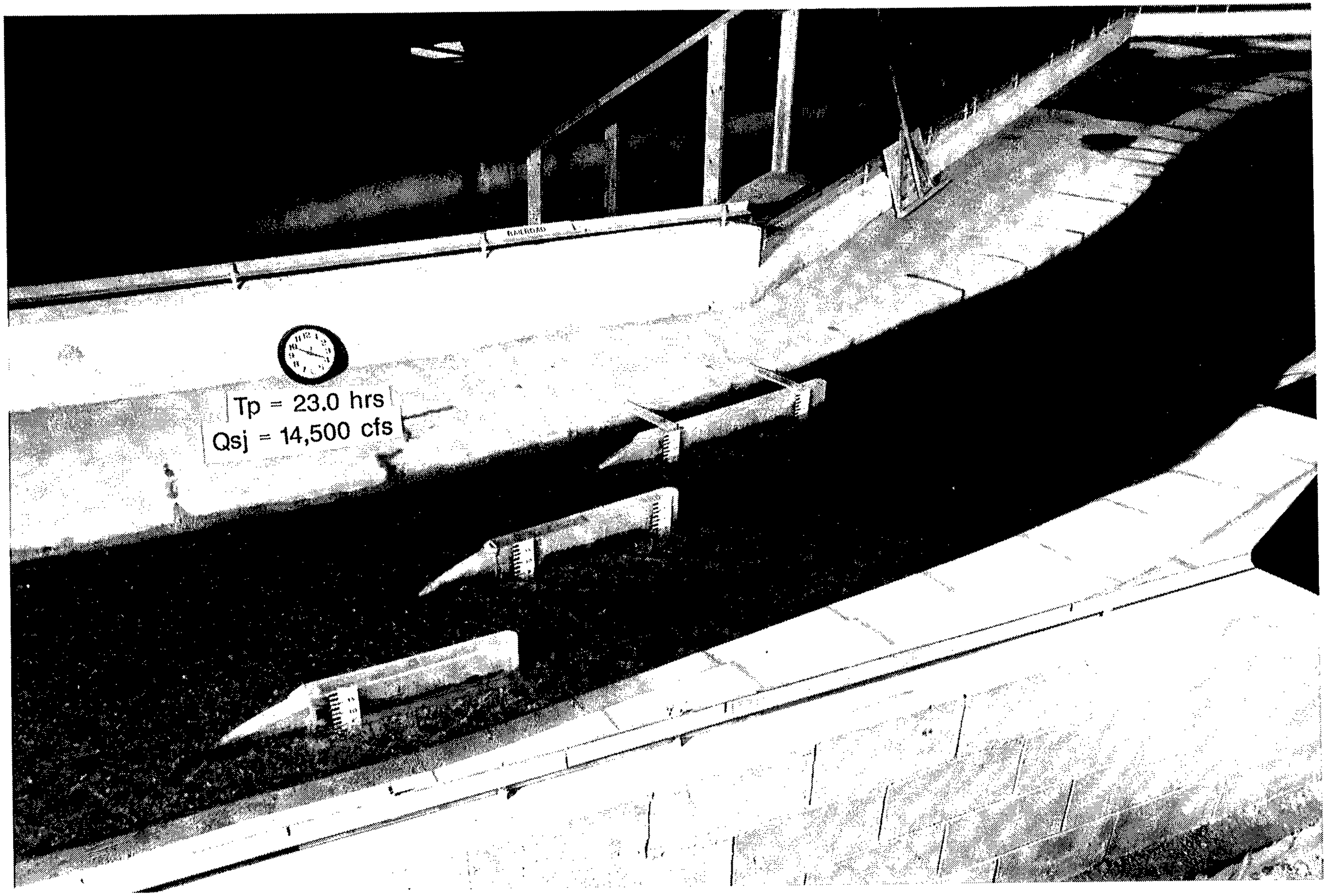


Photo 32. San Juan Creek, type 7 design, flow conditions in the vicinity of the railroad bridge piers during 24-hour storm hydrograph, side view, prototype time 23 hours, Q_{sj} 14,500 cfs (406 cu m/sec)

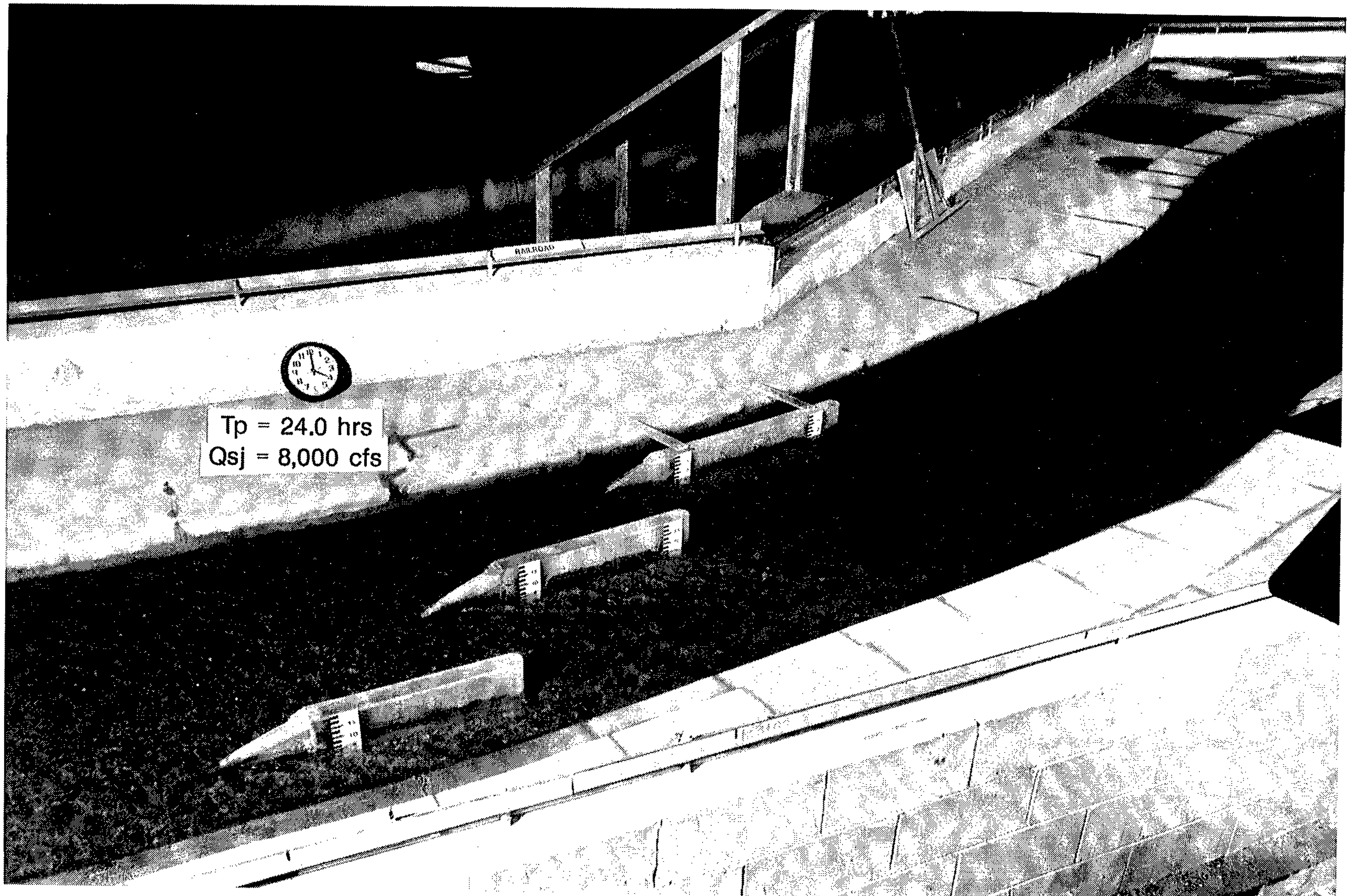


Photo 33. San Juan Creek, type 7 design, flow conditions in the vicinity of the railroad bridge piers during 24-hour storm hydrograph, side view, prototype time 24 hours, Q_{sj} 8,000 cfs (224 cu m/sec)

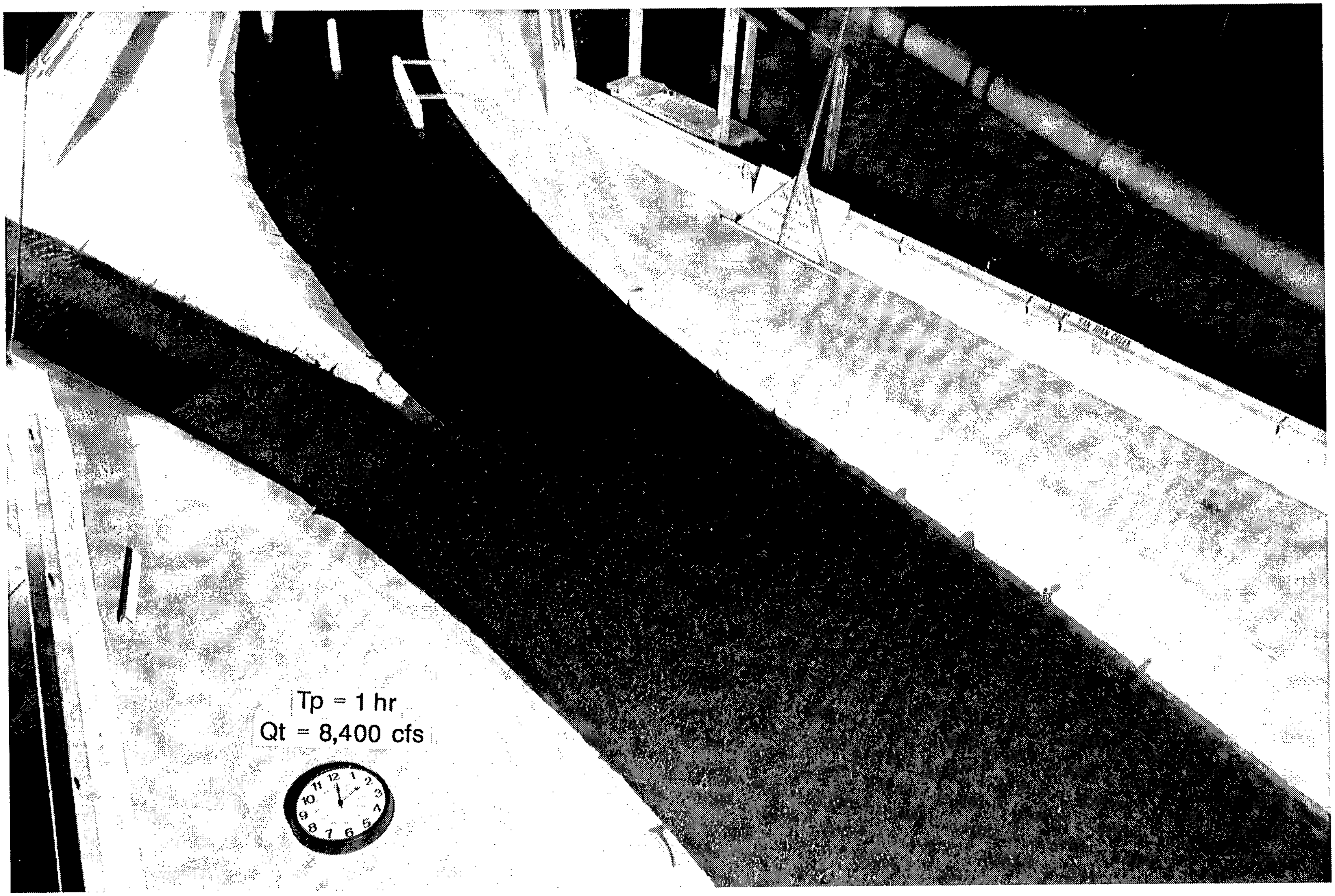


Photo 34. San Juan Creek, type 7 design, flow conditions at confluence with Trabuco Creek during 24-hour storm hydrograph, looking upstream, prototype time 1 hour, Q_{sj} 8,400 cfs (235 cu m/sec)

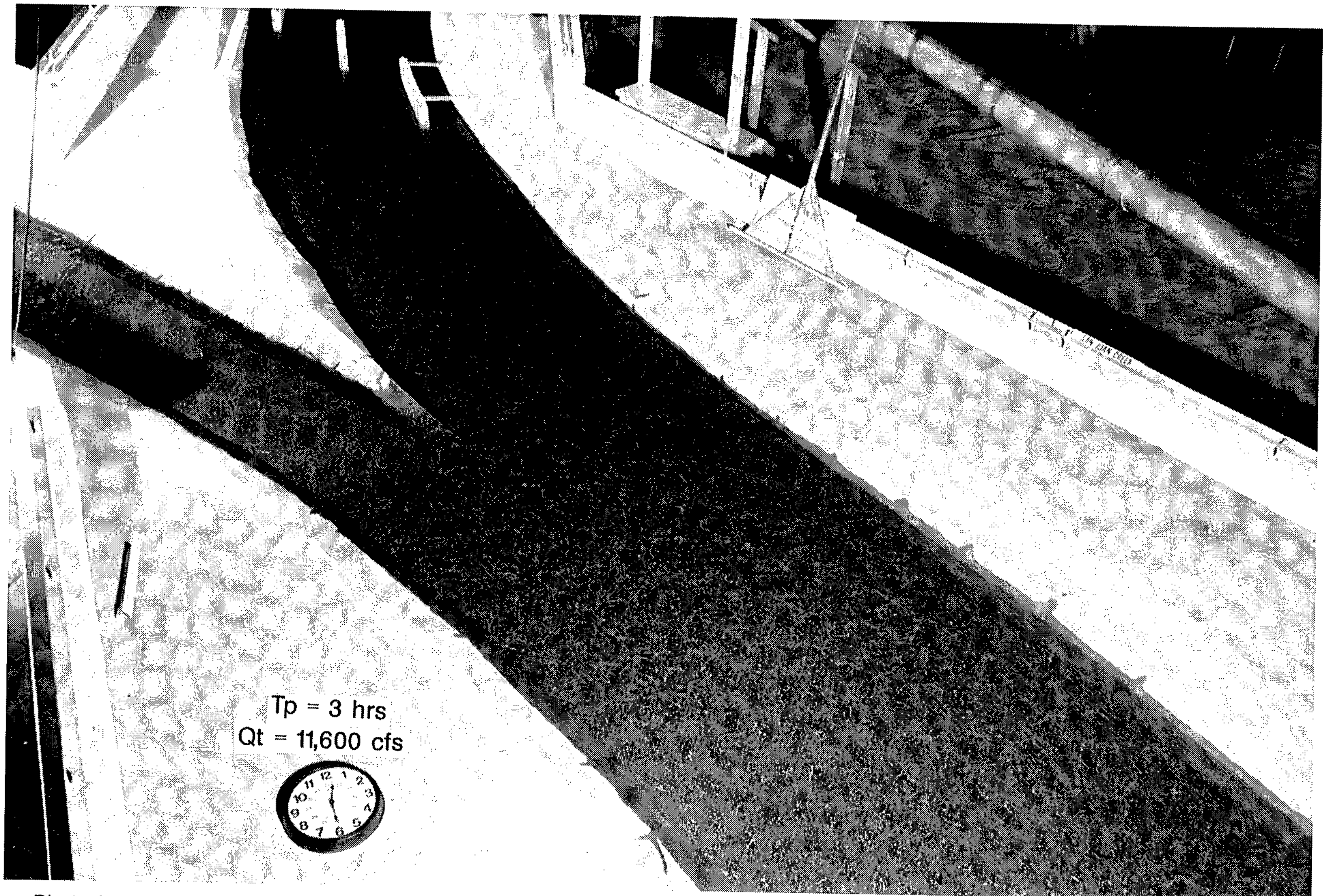


Photo 35. San Juan Creek, type 7 design, flow conditions at confluence with Trabuco Creek during 24-hour storm hydrograph, looking upstream, prototype time 3 hours, Q_{sj} 11,600 cfs (325 cu m/sec)

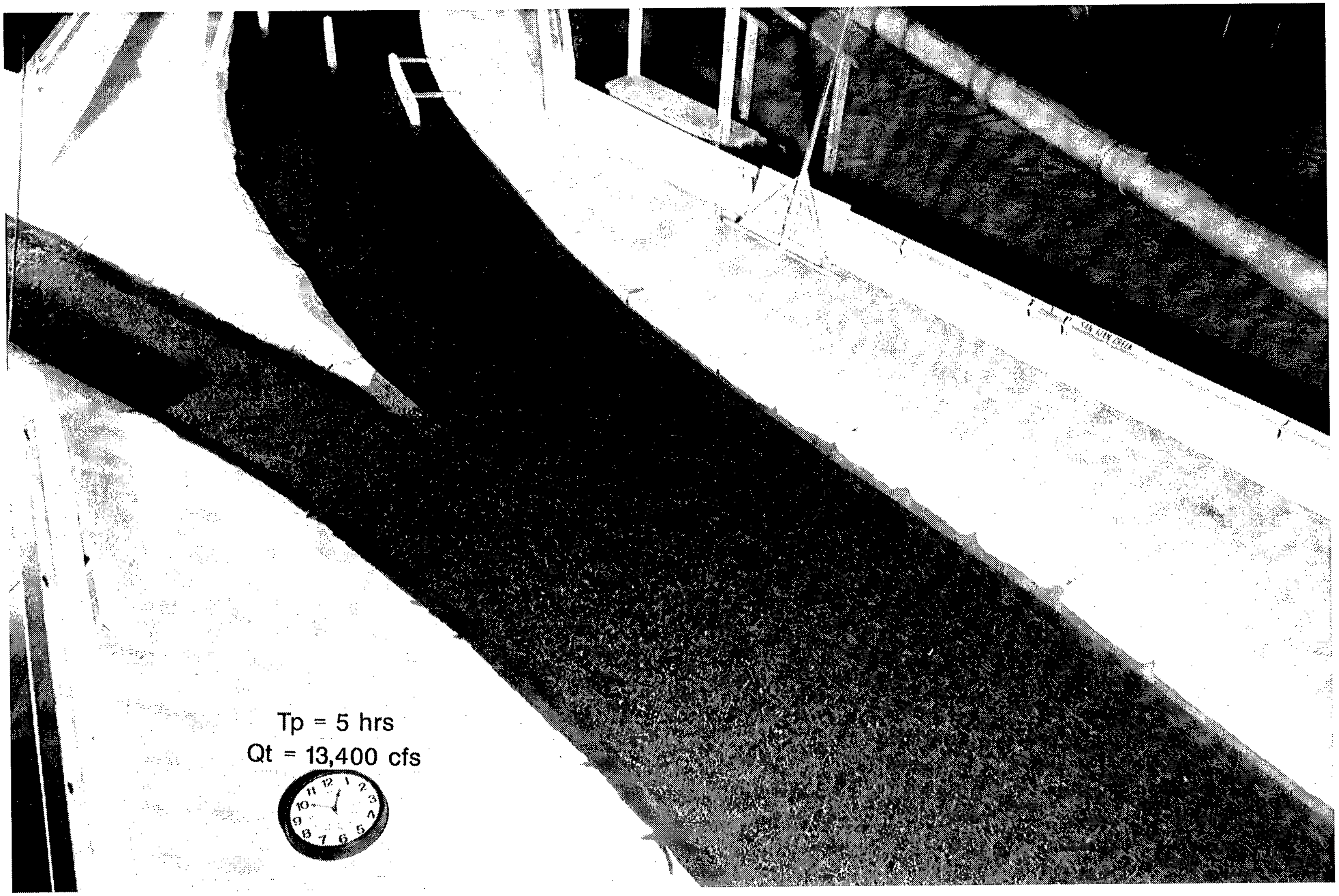


Photo 36. San Juan Creek, type 7 design, flow conditions at confluence with Trabuco Creek during 24-hour storm hydrograph, looking upstream, prototype time 5 hours, Q_{sj} 13,400 cfs (375 cu m/sec)

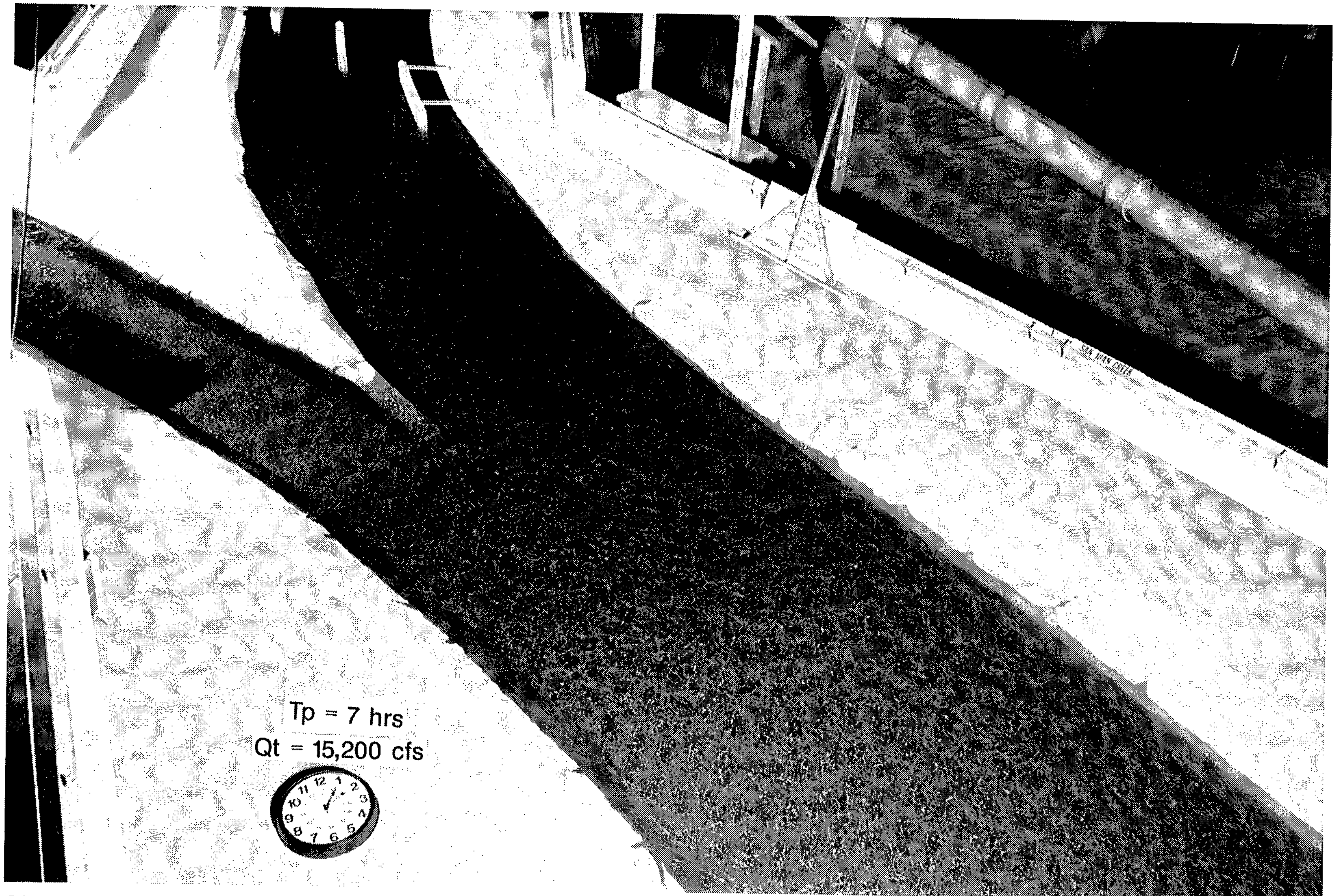


Photo 37. San Juan Creek, type 7 design, flow conditions at confluence with Trabuco Creek during 24-hour storm hydrograph, looking upstream, prototype time 7 hours, Q_{sj} 15,200 cfs (426 cu m/sec)

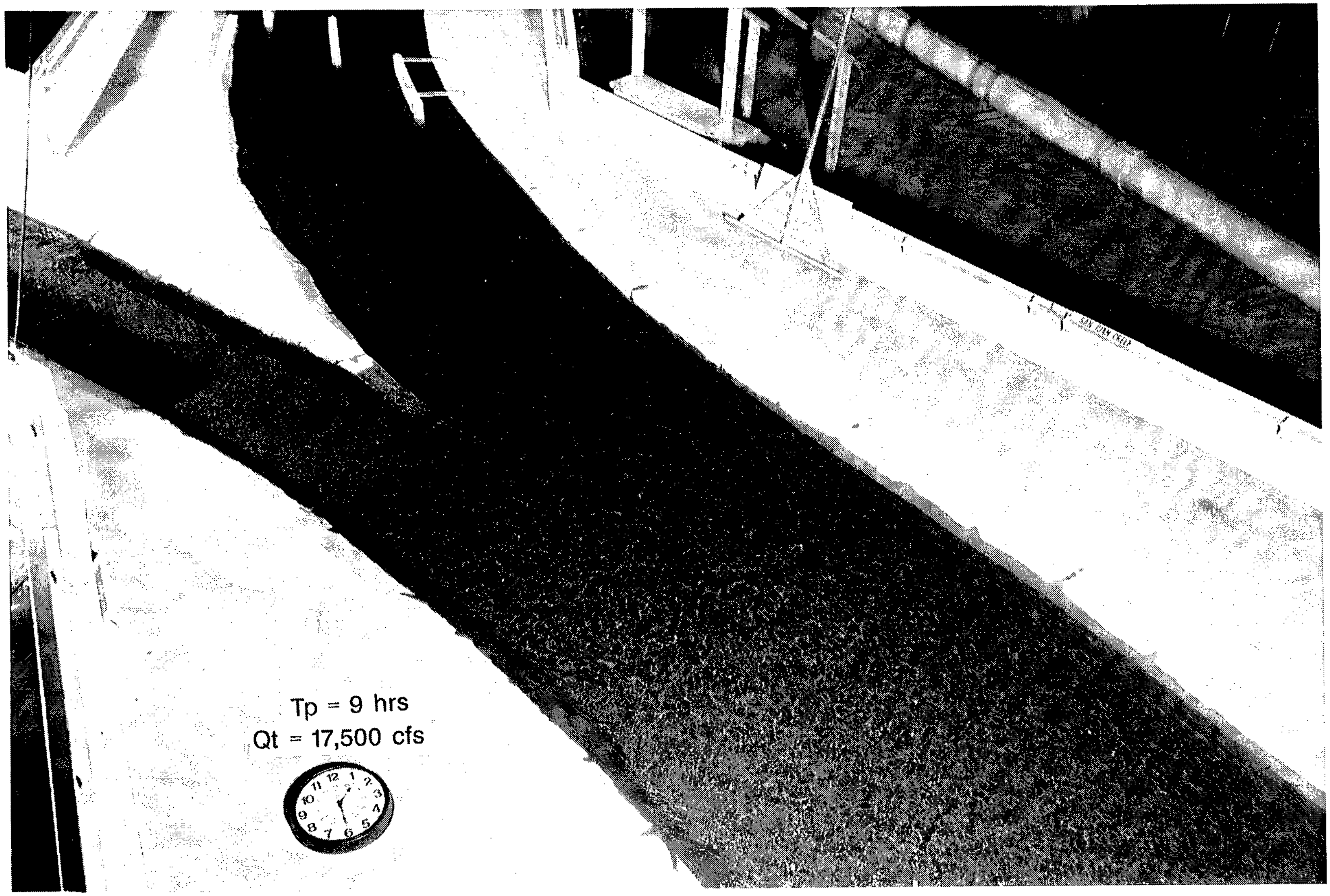


Photo 38. San Juan Creek, type 7 design, flow conditions at confluence with Trabuco Creek during 24-hour storm hydrograph, looking upstream, prototype time 9 hours, Q_{sj} 17,500 cfs (490 cu m/sec)

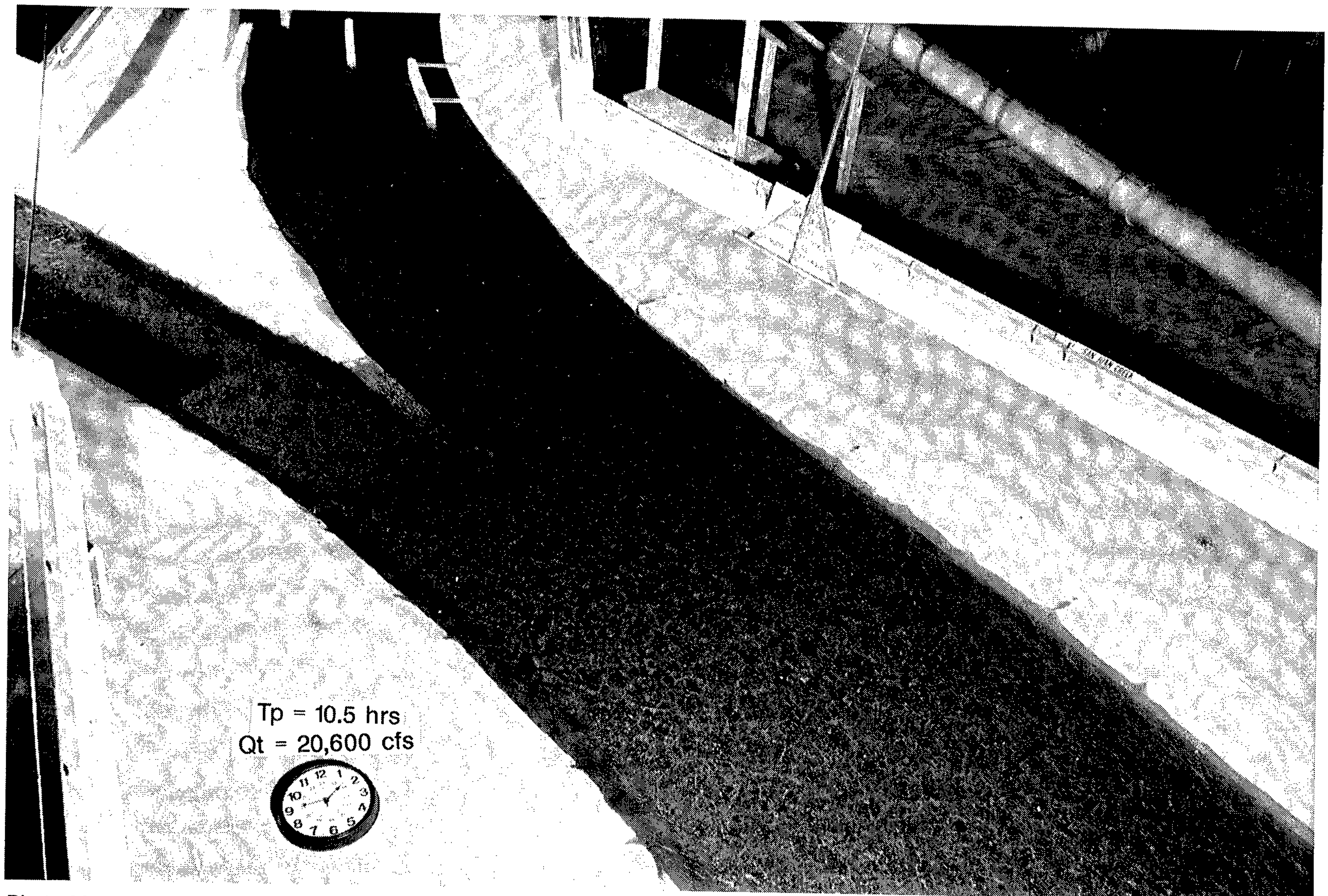


Photo 39. San Juan Creek, type 7 design, flow conditions at confluence with Trabuco Creek during 24-hour storm hydrograph, looking upstream, prototype time 10.5 hours, Q_{sj} 20,600 cfs (577 cu m/sec)

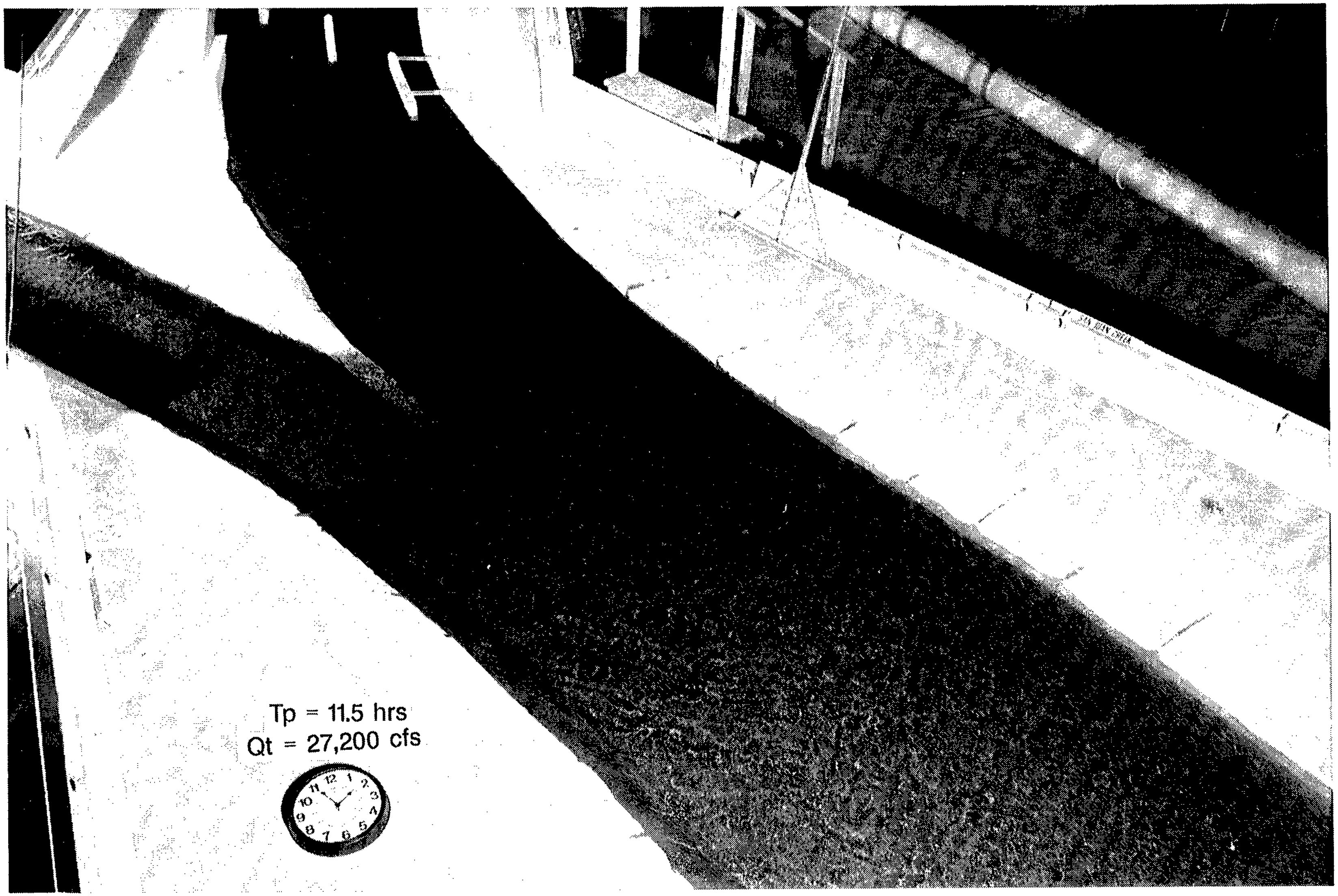


Photo 40. San Juan Creek, type 7 design, flow conditions at confluence with Trabuco Creek during 24-hour storm hydrograph, looking upstream, prototype time 11.5 hours, Q_{sj} 27,200 cfs (762 cu m/sec)

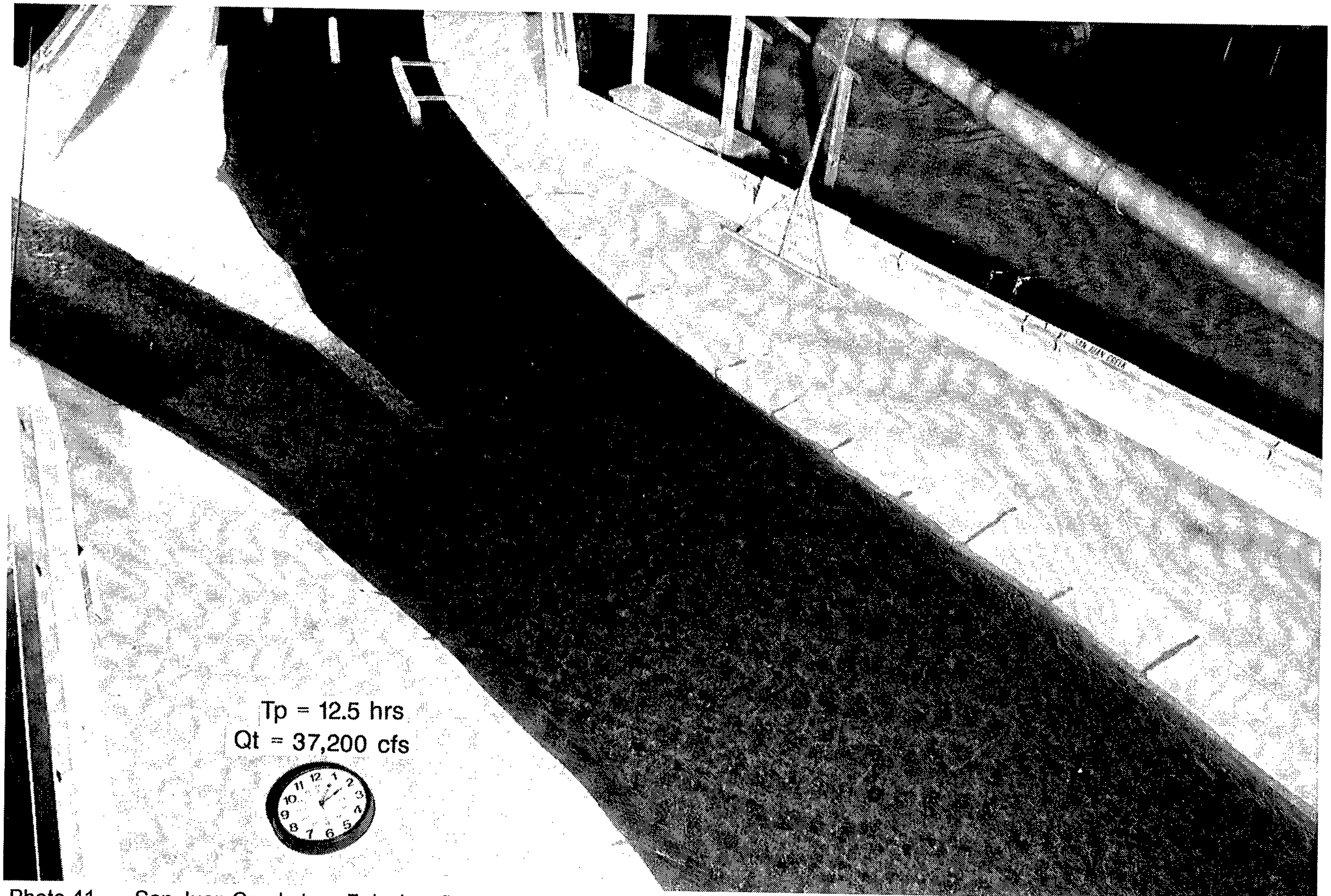


Photo 41. San Juan Creek, type 7 design, flow conditions at confluence with Trabuco Creek during 24-hour storm hydrograph, looking upstream, prototype time 12.5 hours, Q_{sj} 37,200 cfs (1,042 cu m/sec)

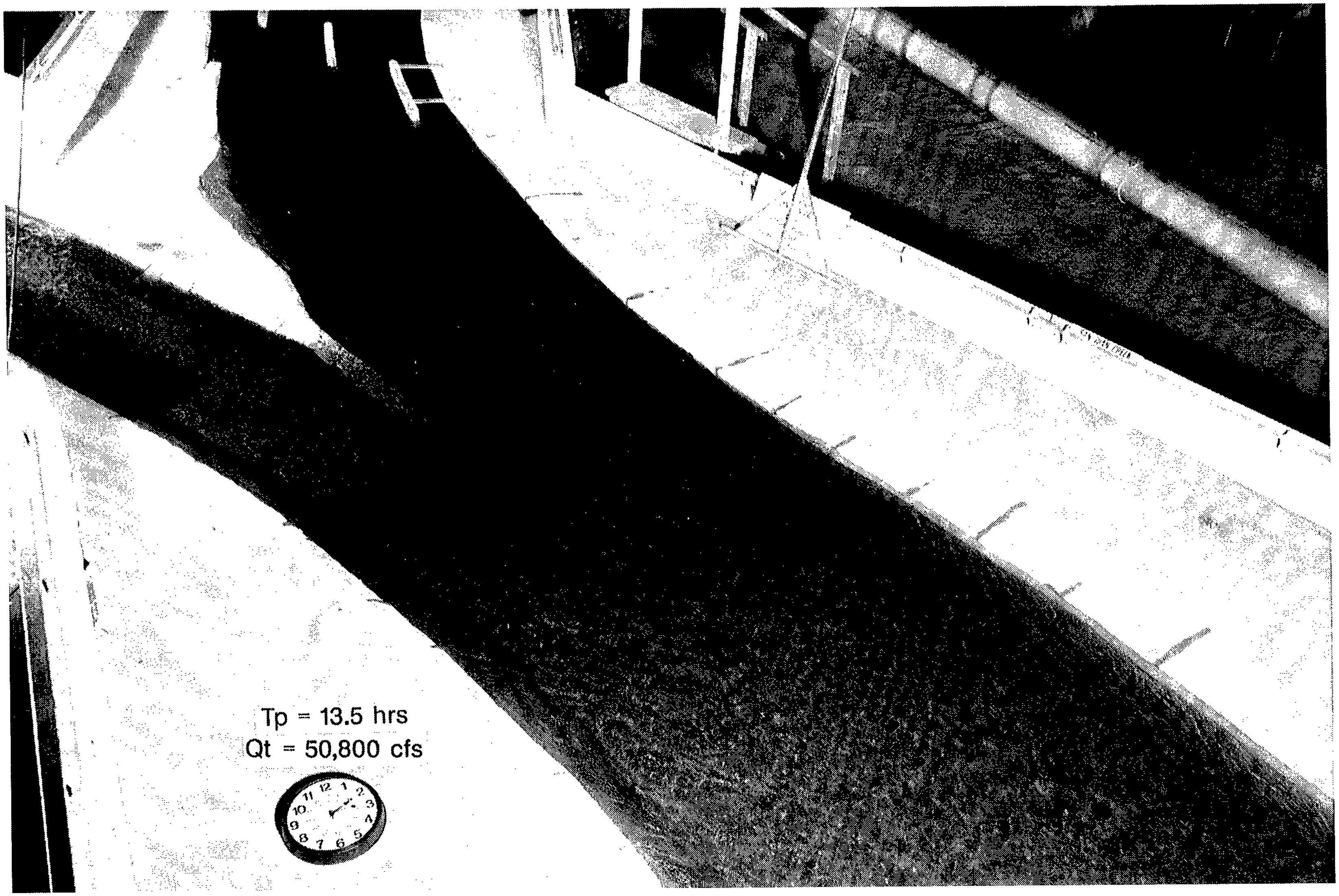


Photo 42. San Juan Creek, type 7 design, flow conditions at confluence with Trabuco Creek during 24-hour storm hydrograph, looking upstream, prototype time 13.5 hours, Q_{sj} 50,800 cfs (1,422 cu m/sec)

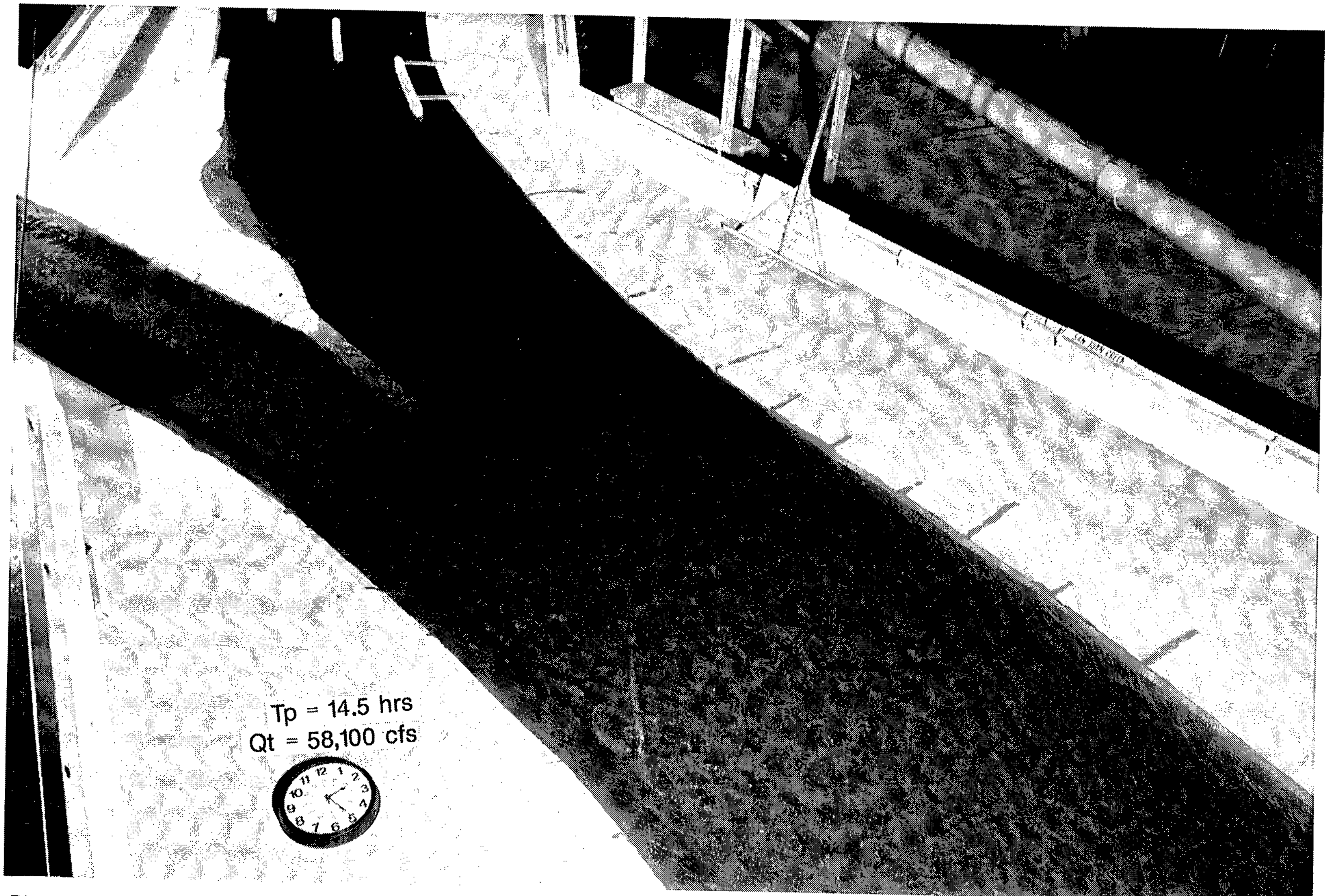


Photo 43. San Juan Creek, type 7 design, flow conditions at confluence with Trabuco Creek during 24-hour storm hydrograph, looking upstream, prototype time 14.5 hours, Q_{sj} 58,100 cfs (1,627 cu m/sec)

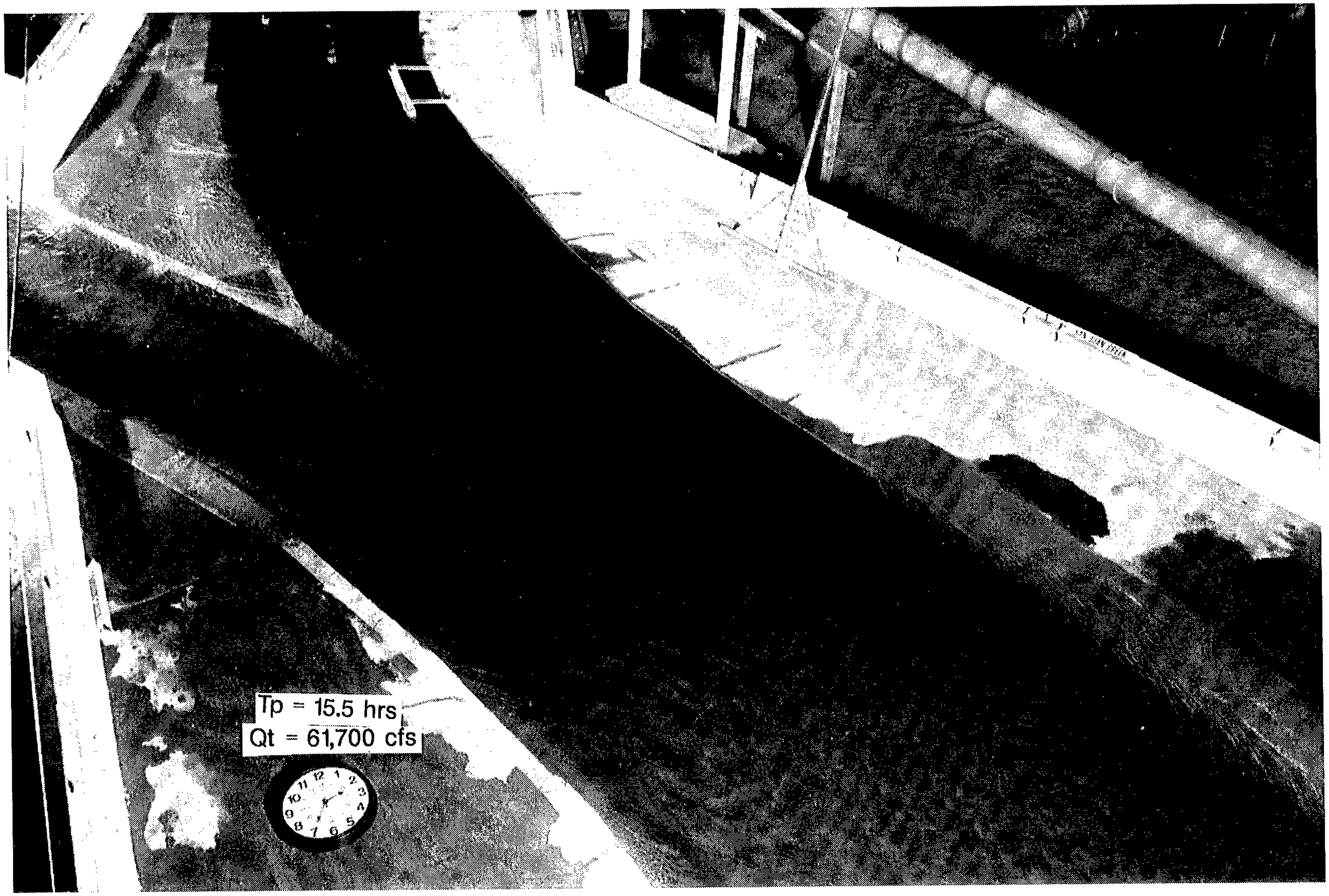


Photo 44. San Juan Creek, type 7 design, flow conditions at confluence with Trabuco Creek during 24-hour storm hydrograph, looking upstream, prototype time 15.5 hours, Q_{sj} 61,700 cfs (1,728 cu m/sec)

Photo 45. San Juan Creek, type 7 design, flow conditions at confluence with Trabuco Creek during 24-hour storm hydrograph, looking upstream, prototype time 16 hours, Q_{sj} 61,600 cfs (1,725 cu m/sec)

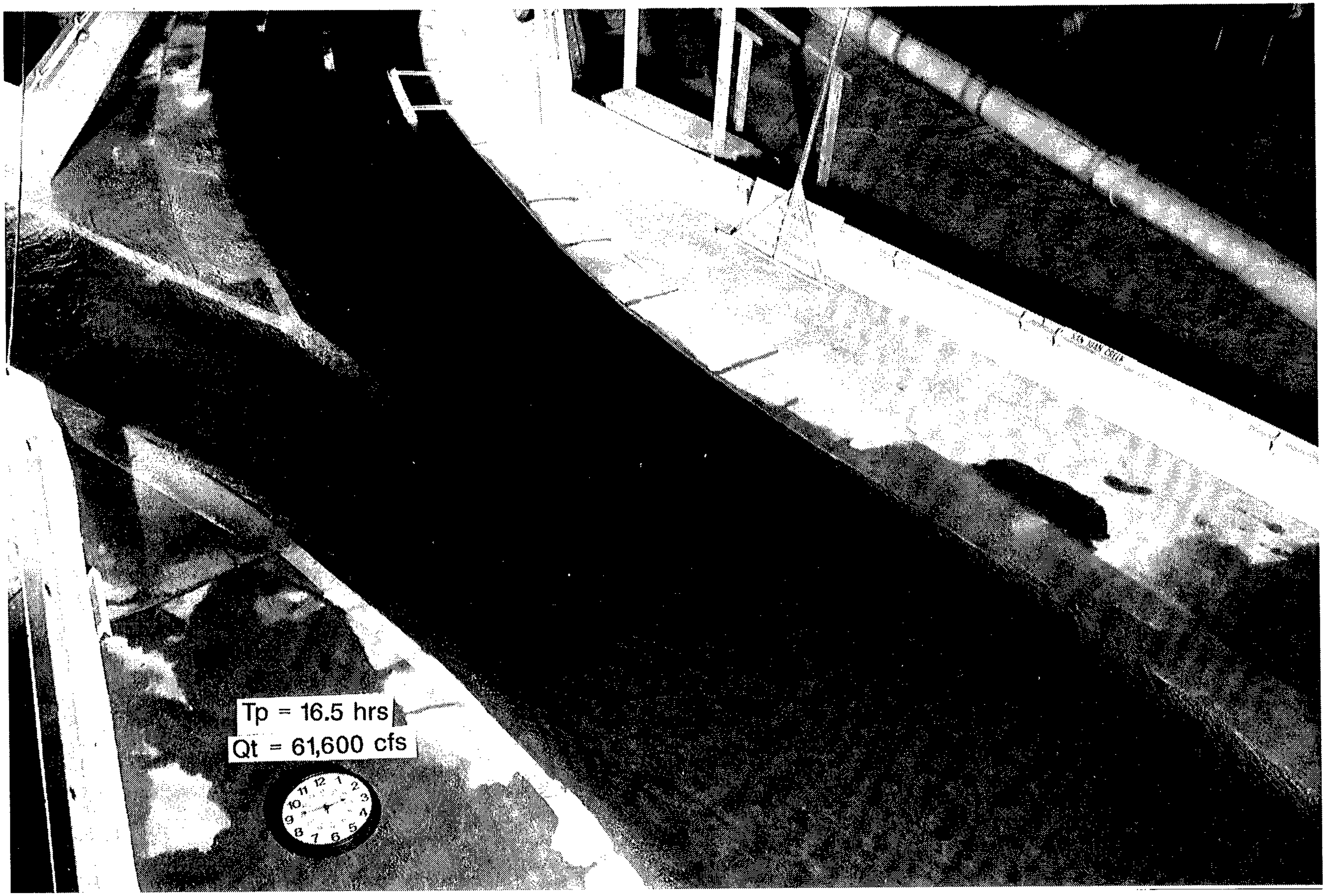


Photo 46. San Juan Creek, type 7 design, flow conditions at confluence with Trabuco Creek during 24-hour storm hydrograph, looking upstream, prototype time 16.5 hours, Q_{sj} 61,600 cfs (1,725 cu m/sec)

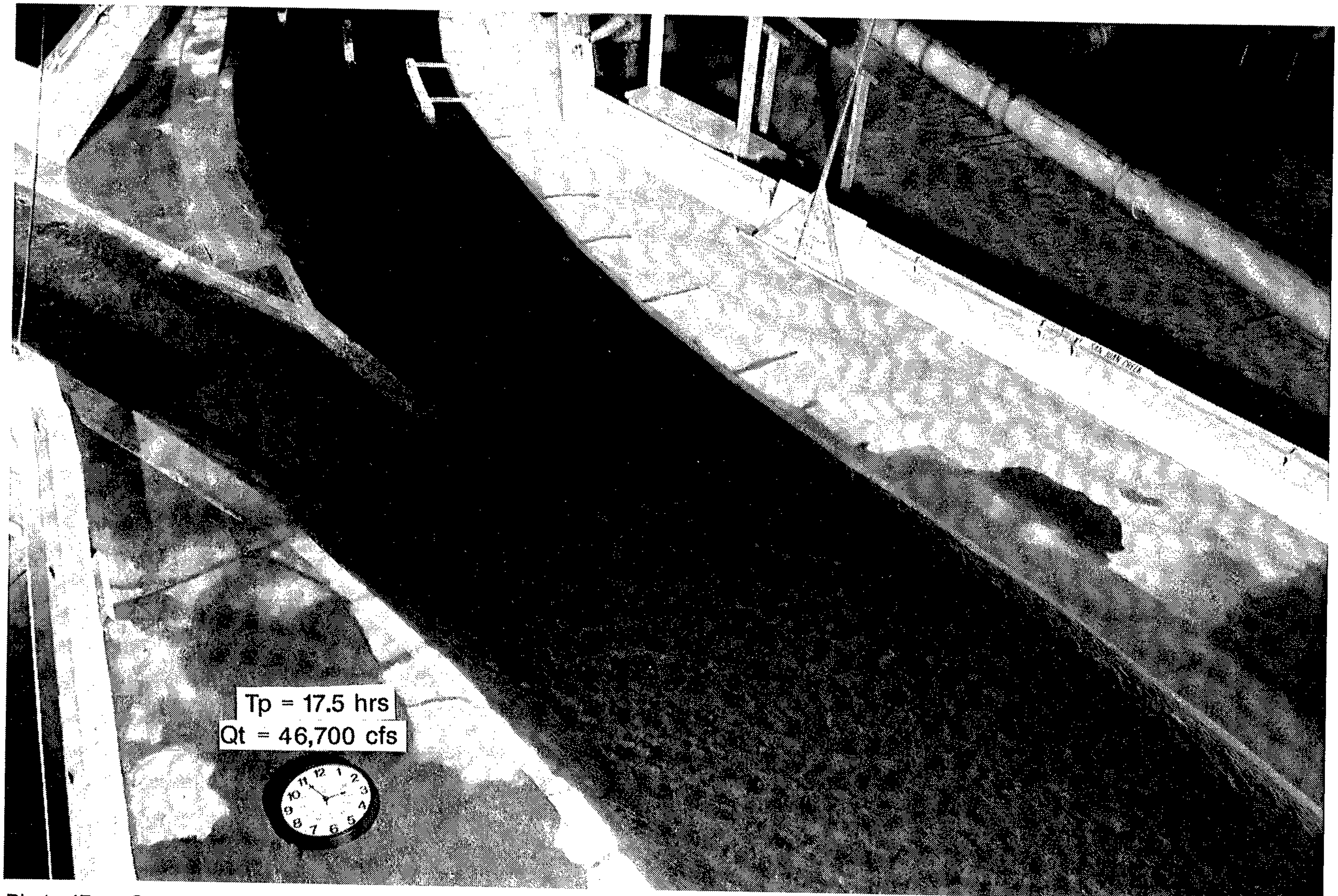


Photo 47. San Juan Creek, type 7 design, flow conditions at confluence with Trabuco Creek during 24-hour storm hydrograph, looking upstream, prototype time 17.5 hours, Q_{sj} 46,700 cfs (1,308 cu m/sec)

Photo 48. San Juan Creek, type 7 design, flow conditions at confluence with Trabuco Creek during 24-hour storm hydrograph, looking upstream, prototype time 18.5 hours, Q_{sj} 33,800 cfs (946 cu m/sec)

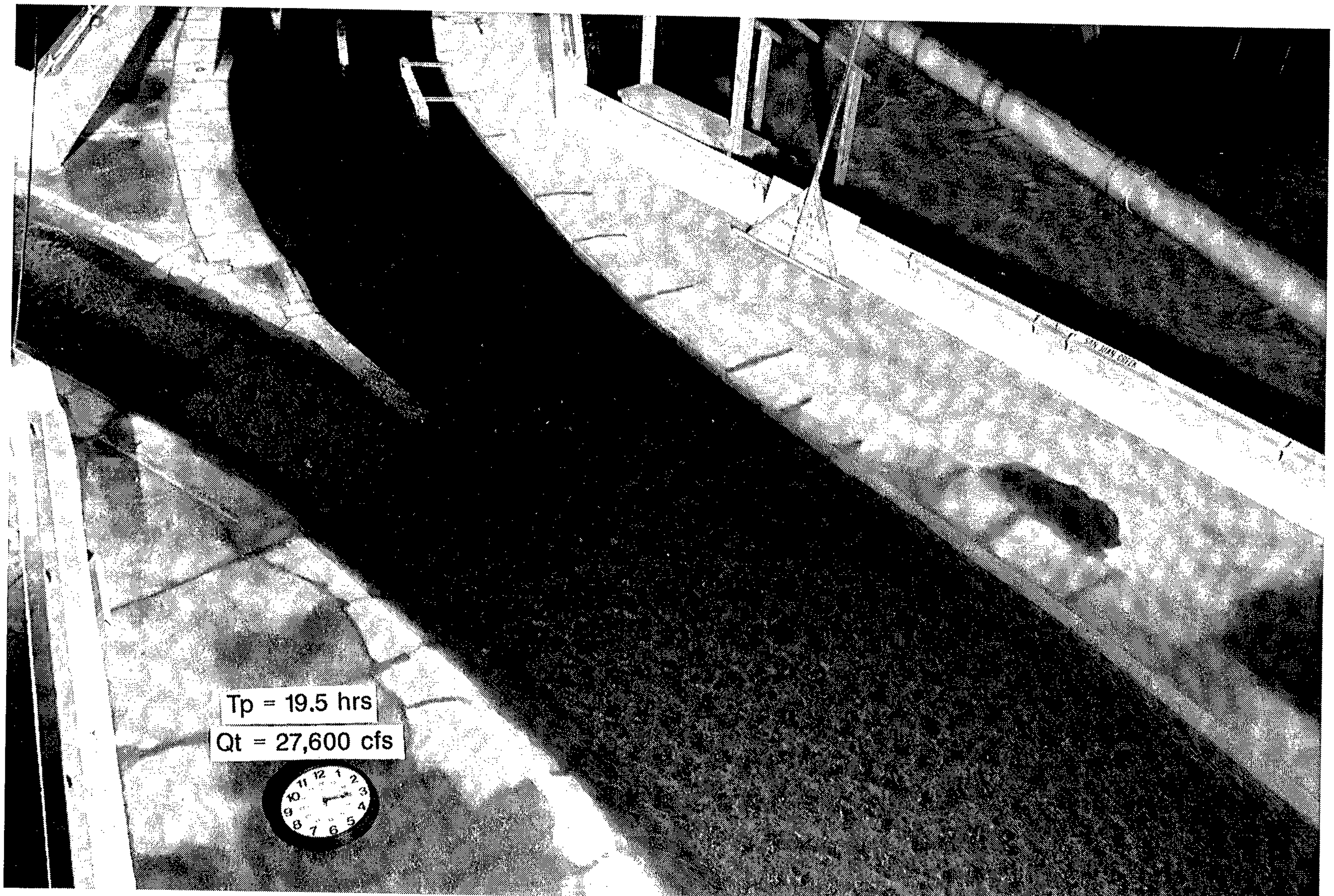


Photo 49. San Juan Creek, type 7 design, flow conditions at confluence with Trabuco Creek during 24-hour storm hydrograph, looking upstream, prototype time 19.5 hours, Q_{sj} 27,600 cfs (773 cu m/sec)

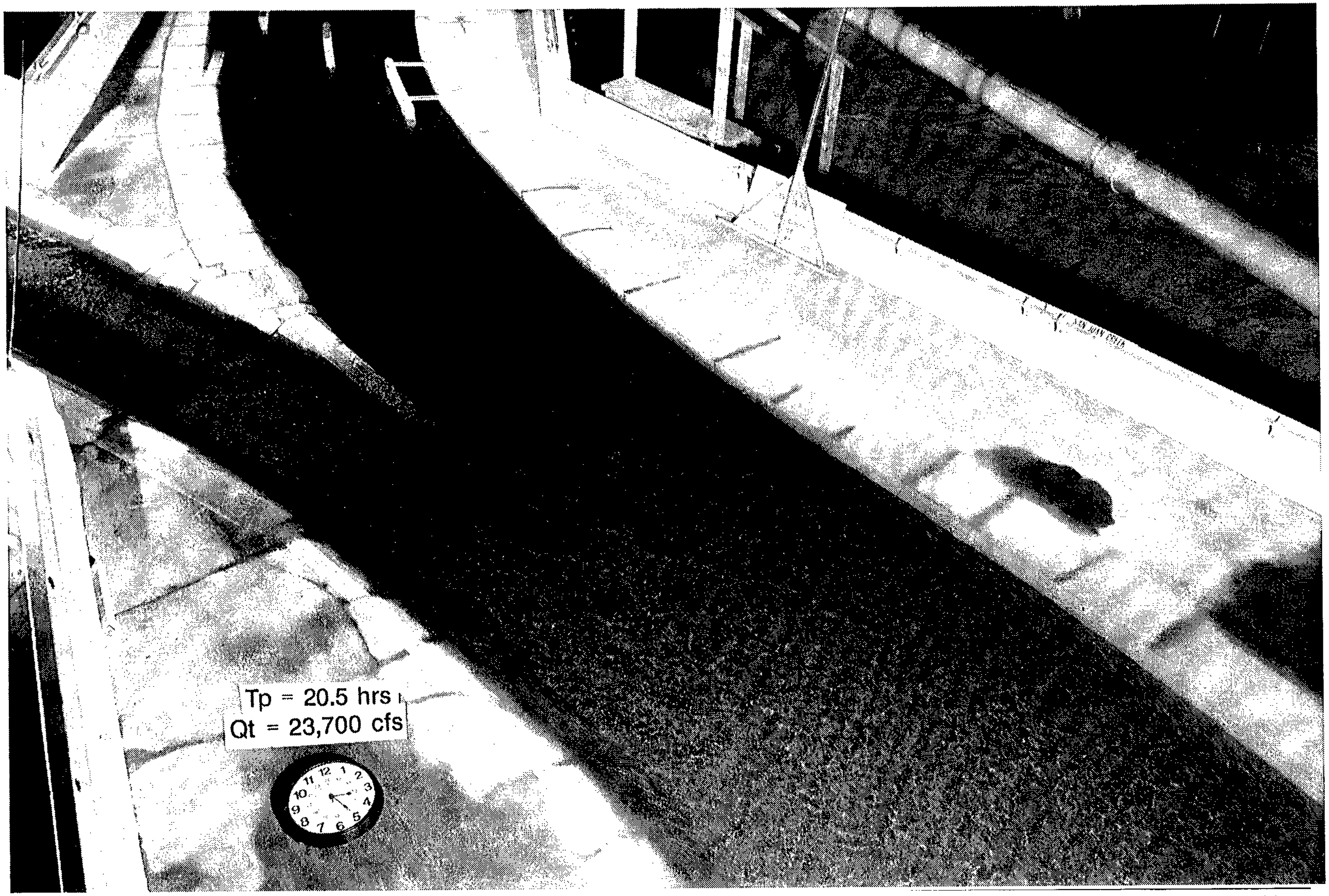


Photo 50. San Juan Creek, type 7 design, flow conditions at confluence with Trabuco Creek during 24-hour storm hydrograph, looking upstream, prototype time 20.5 hours, Q_{sj} 23,700 cfs (664 cu m/sec)

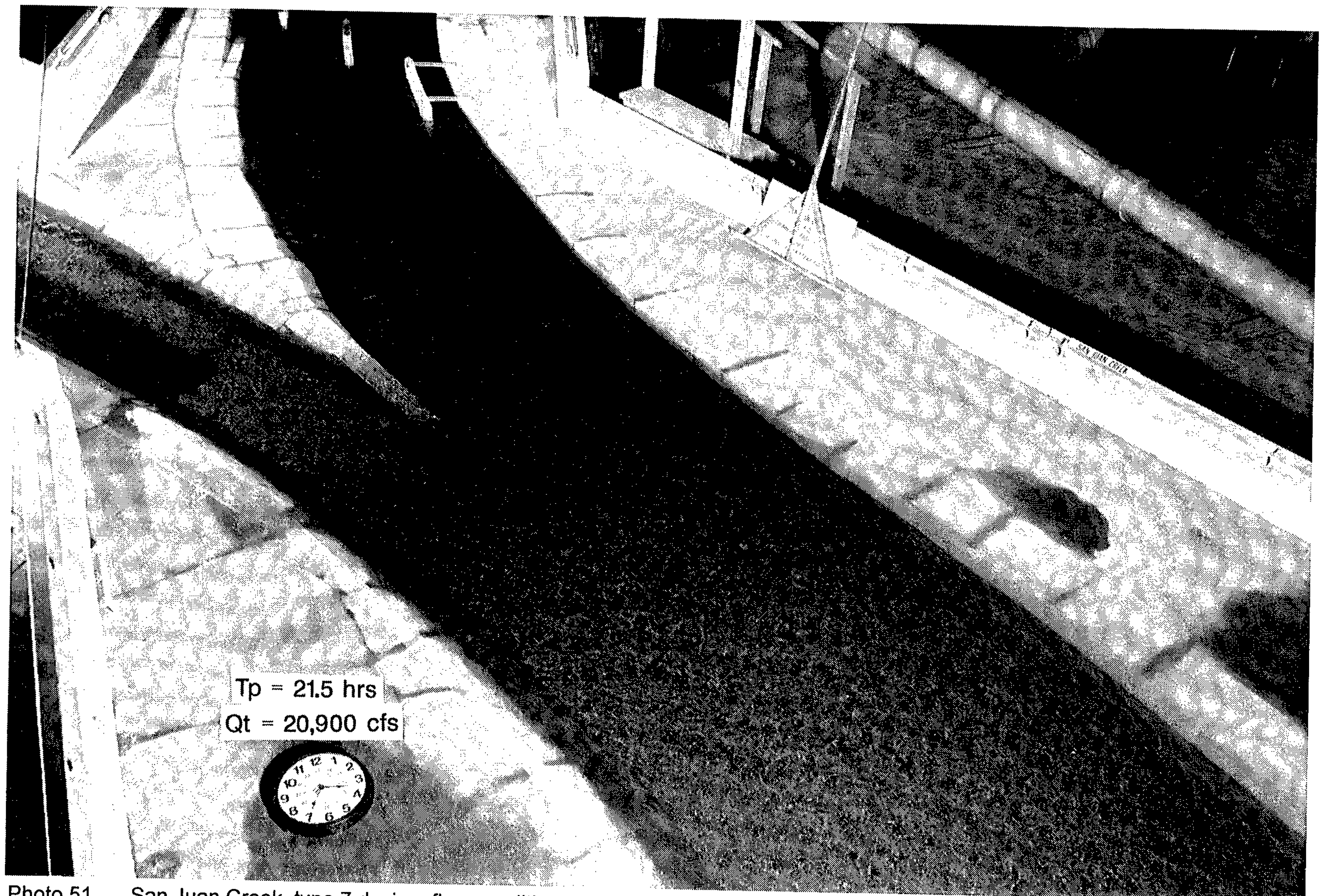


Photo 51. San Juan Creek, type 7 design, flow conditions at confluence with Trabuco Creek during 24-hour storm hydrograph, looking upstream, prototype time 21.5 hours, Q_{sj} 20,900 cfs (585 cu m/sec)

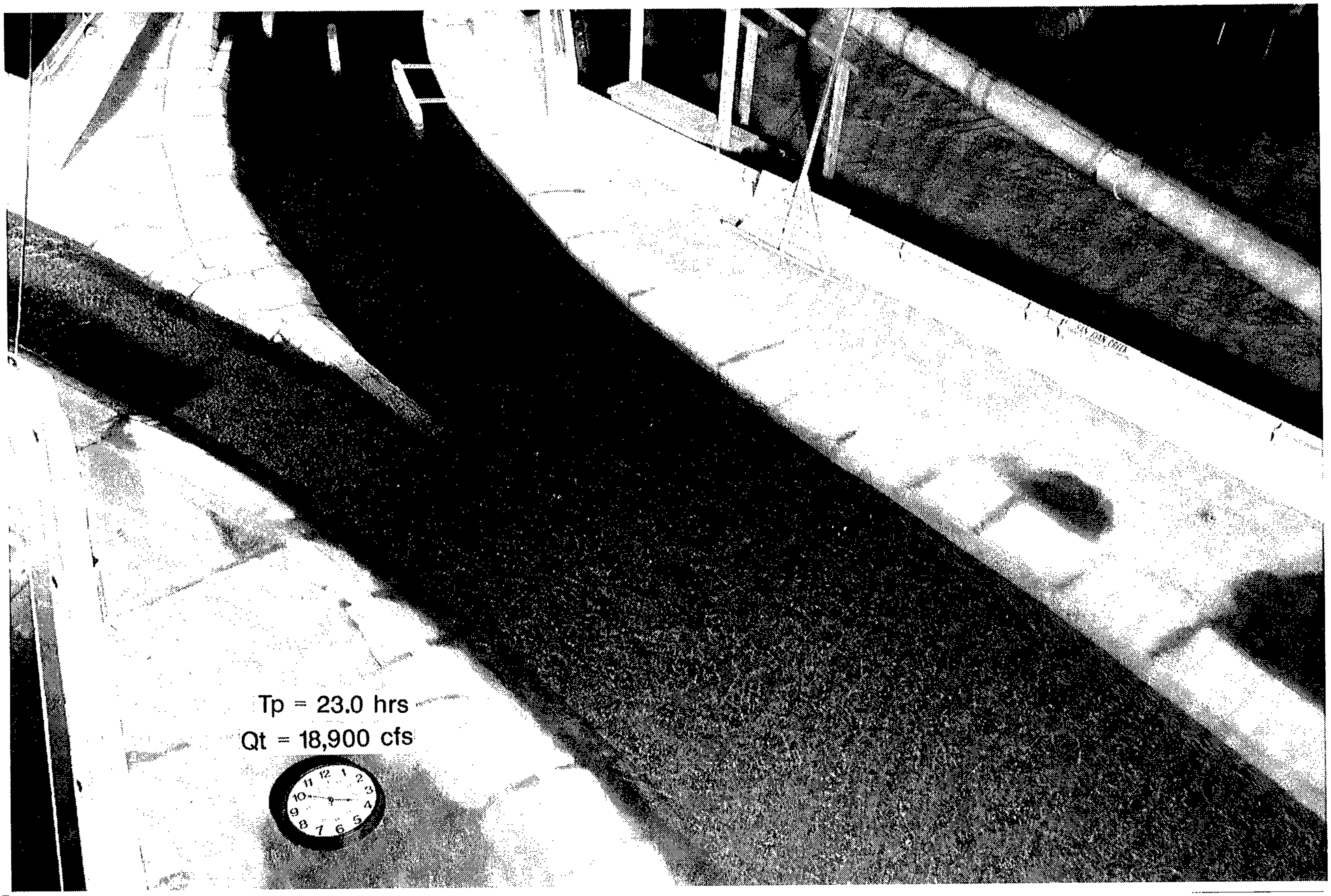


Photo 52. San Juan Creek, type 7 design, flow conditions at confluence with Trabuco Creek during 24-hour storm hydrograph, looking upstream, prototype time 23 hours, Q_{sj} 18,900 cfs (529 cu m/sec)

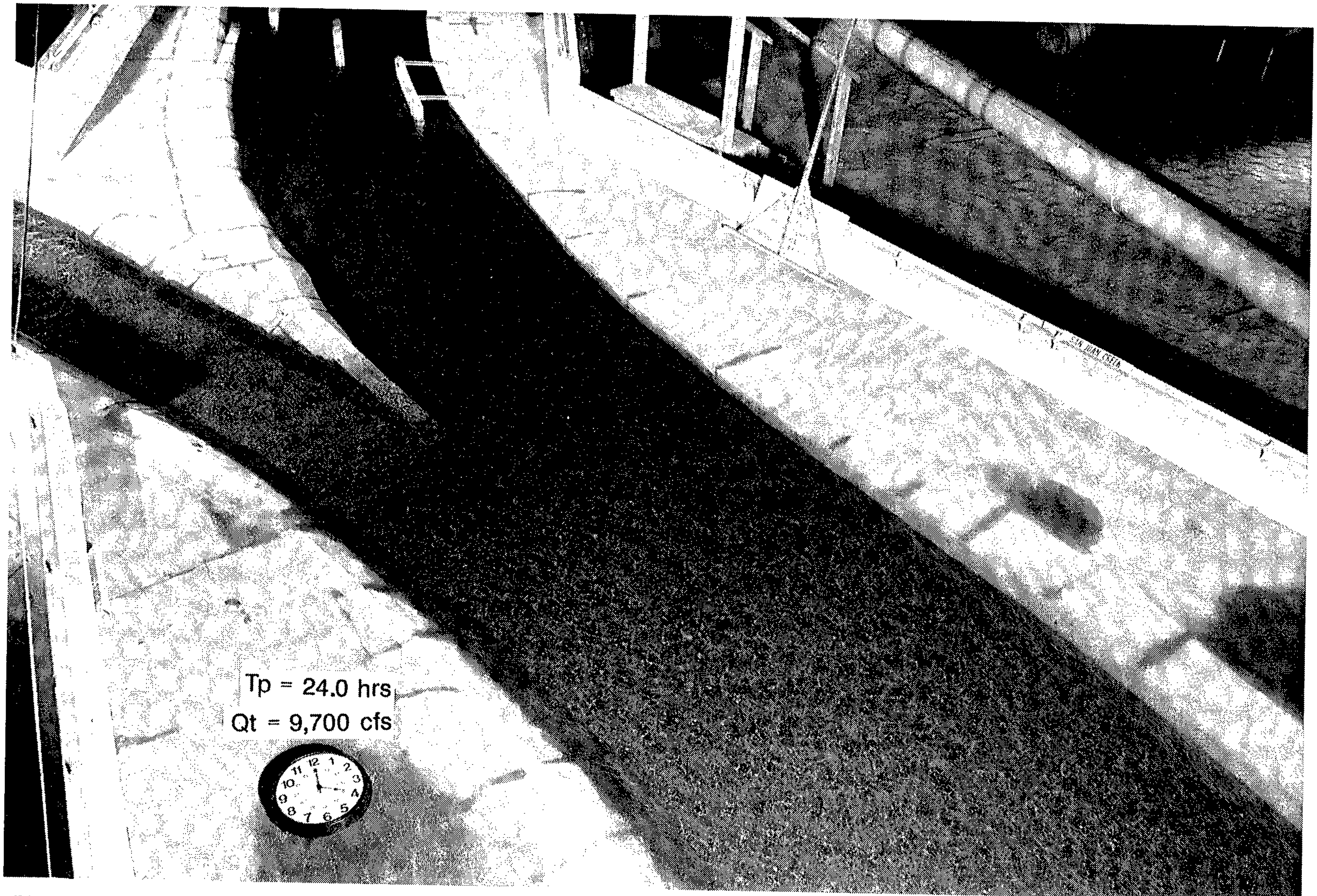


Photo 53. San Juan Creek, type 7 design, flow conditions at confluence with Trabuco Creek during 24-hour storm hydrograph, looking upstream, prototype time 24 hours, Q_{sj} 9,700 cfs (272 cu m/sec)

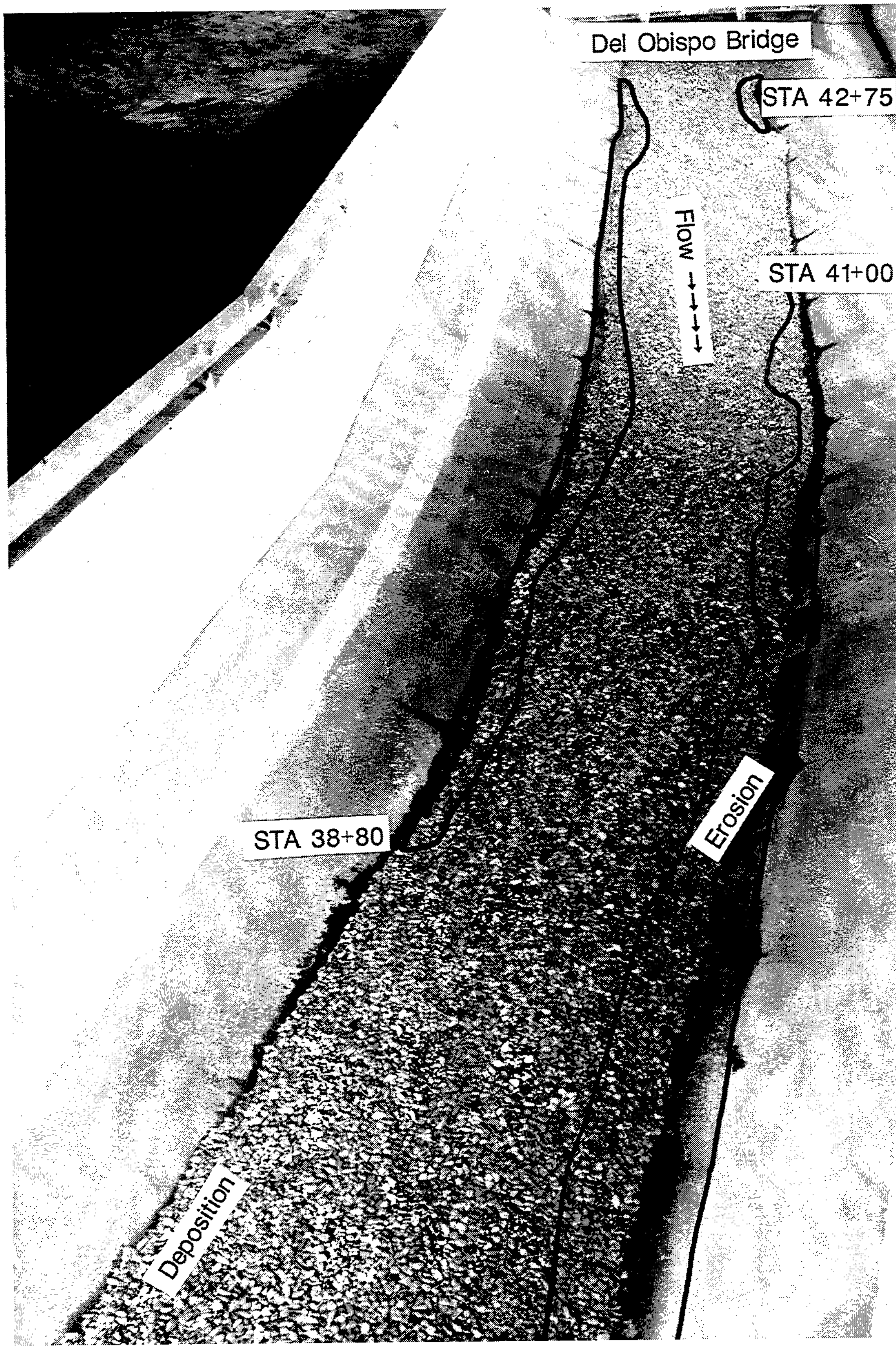


Photo 54. Trabuco Creek, type 7 design, 24-hour storm hydrograph, scour analysis test, gravel bed, potential scour areas around sta 38+80

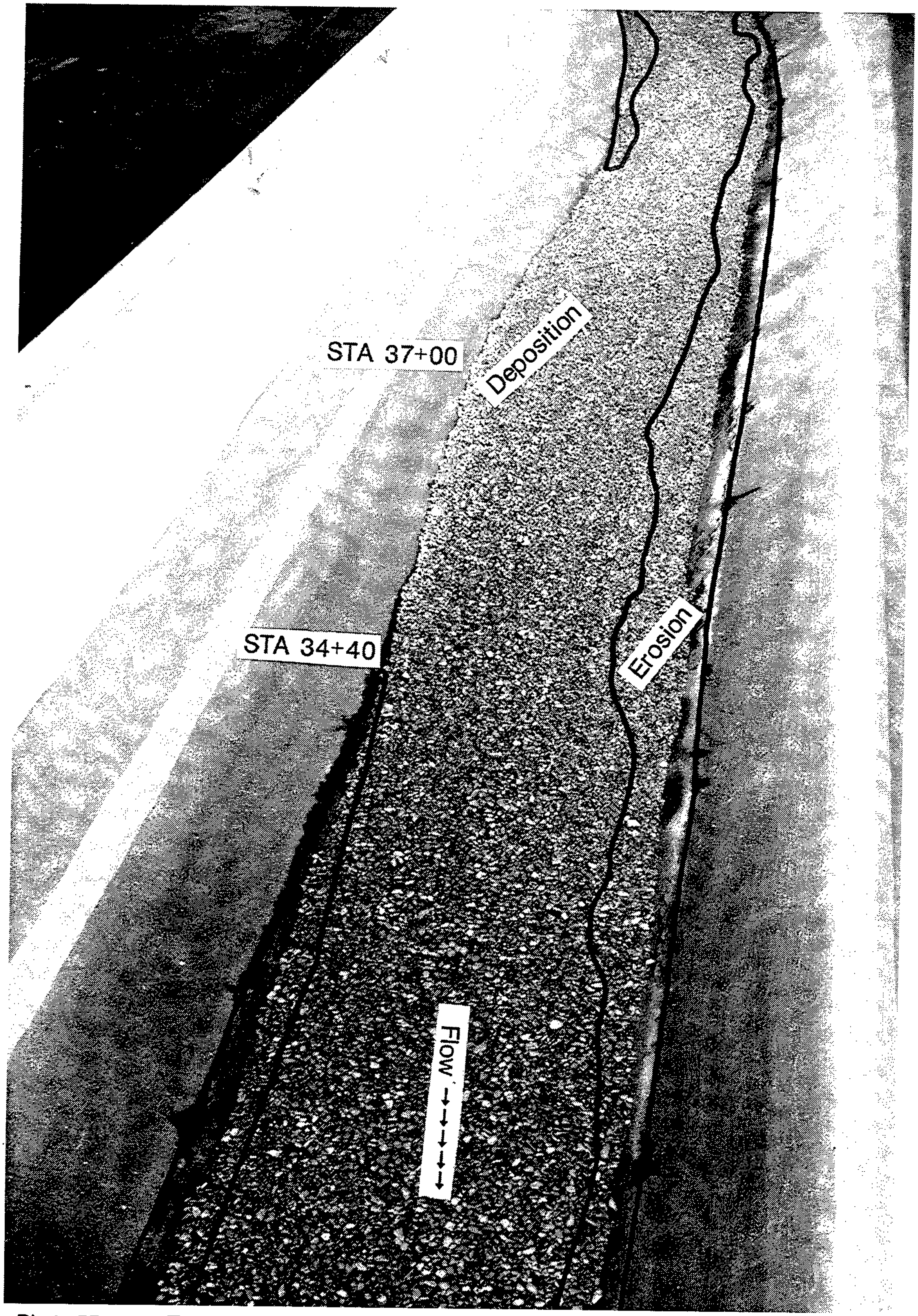


Photo 55. Trabuco Creek, type 7 design, 24-hour storm hydrograph, scour analysis test, potential scour areas

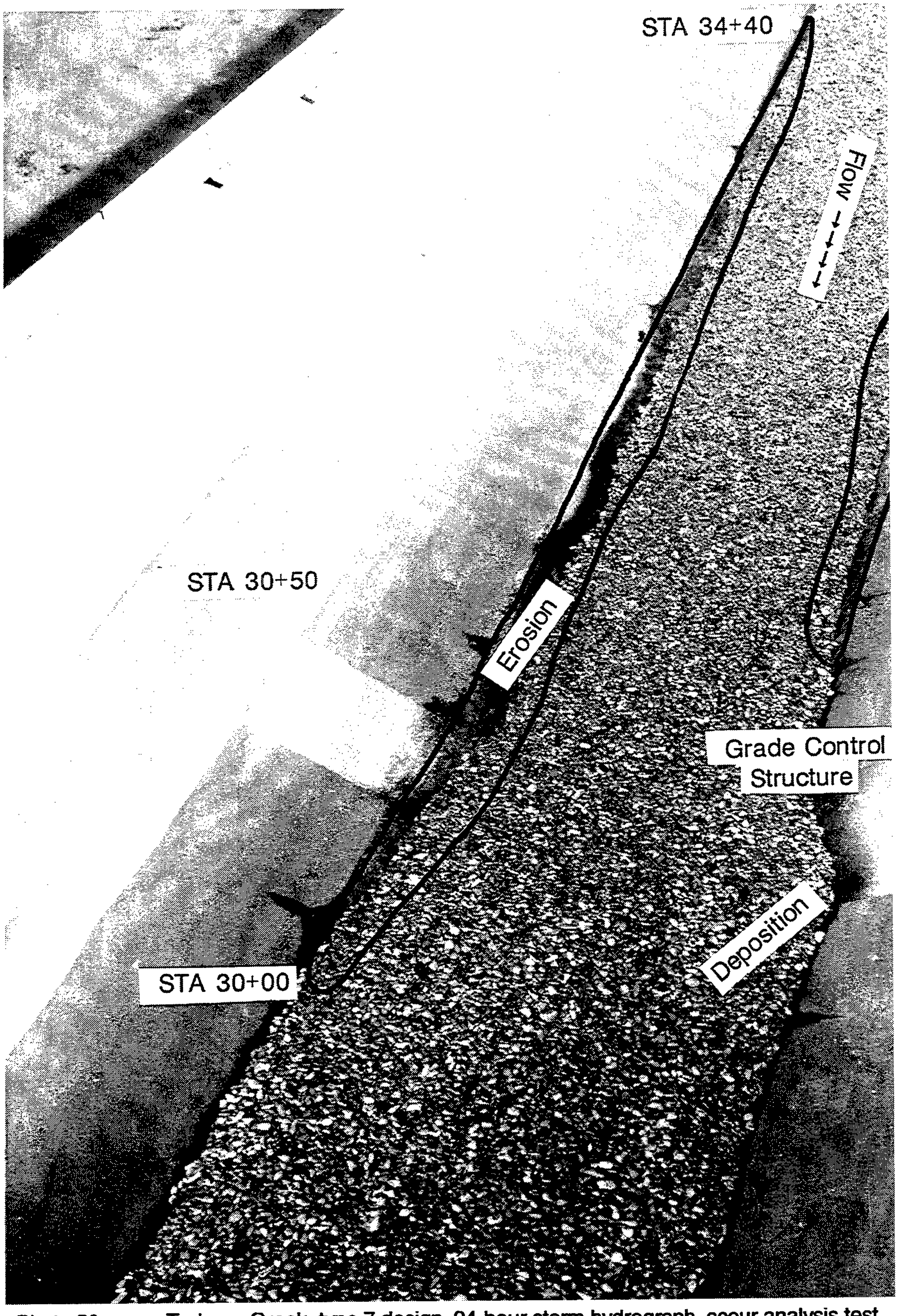


Photo 56. Trabuco Creek, type 7 design, 24-hour storm hydrograph, scour analysis test, potential scour areas around grade control structure

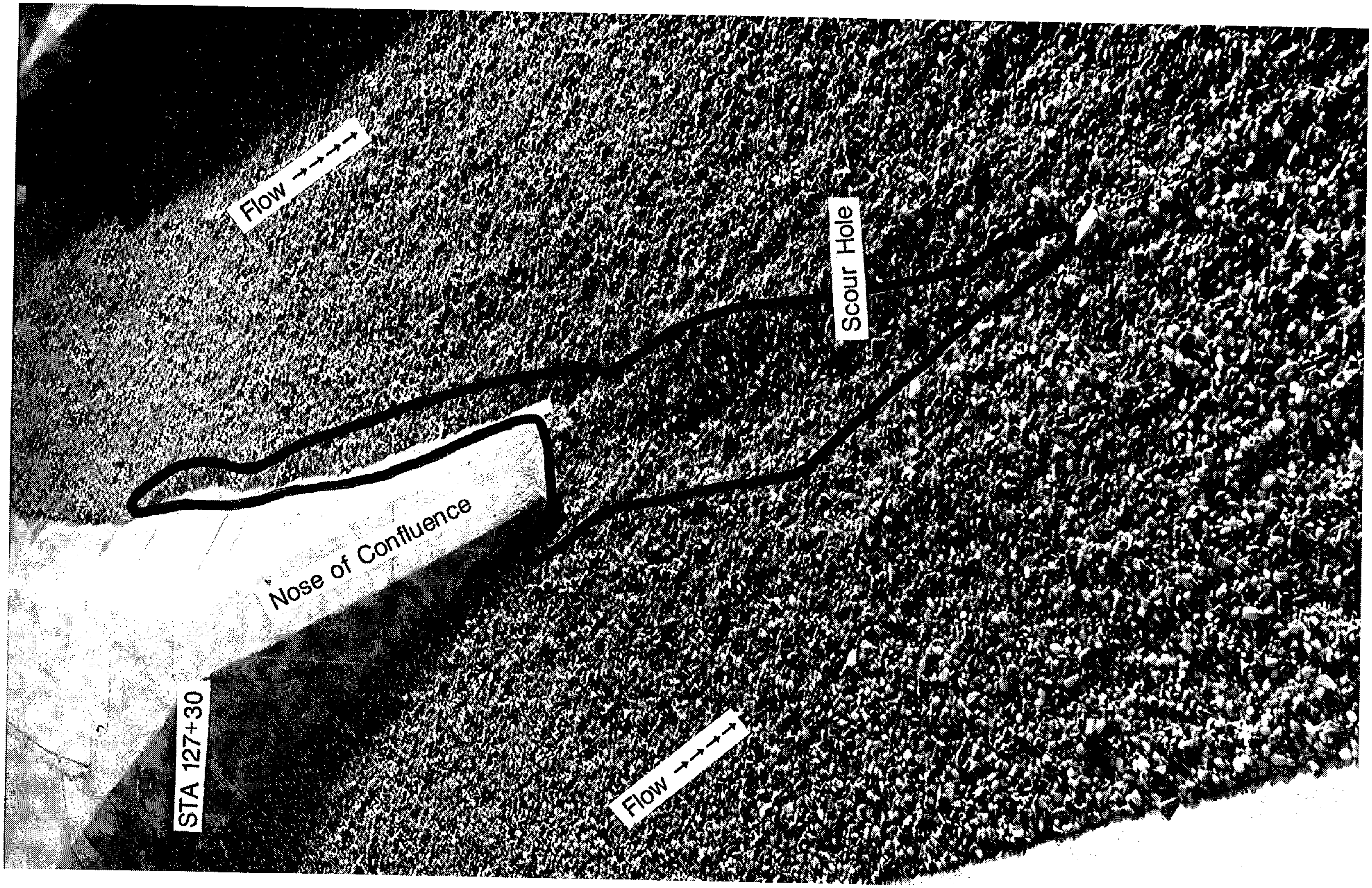


Photo 57. Confluence of San Juan and Trabuco Creeks, type 7 design, 24-hour storm hydrograph, scour analysis test, potential scour area

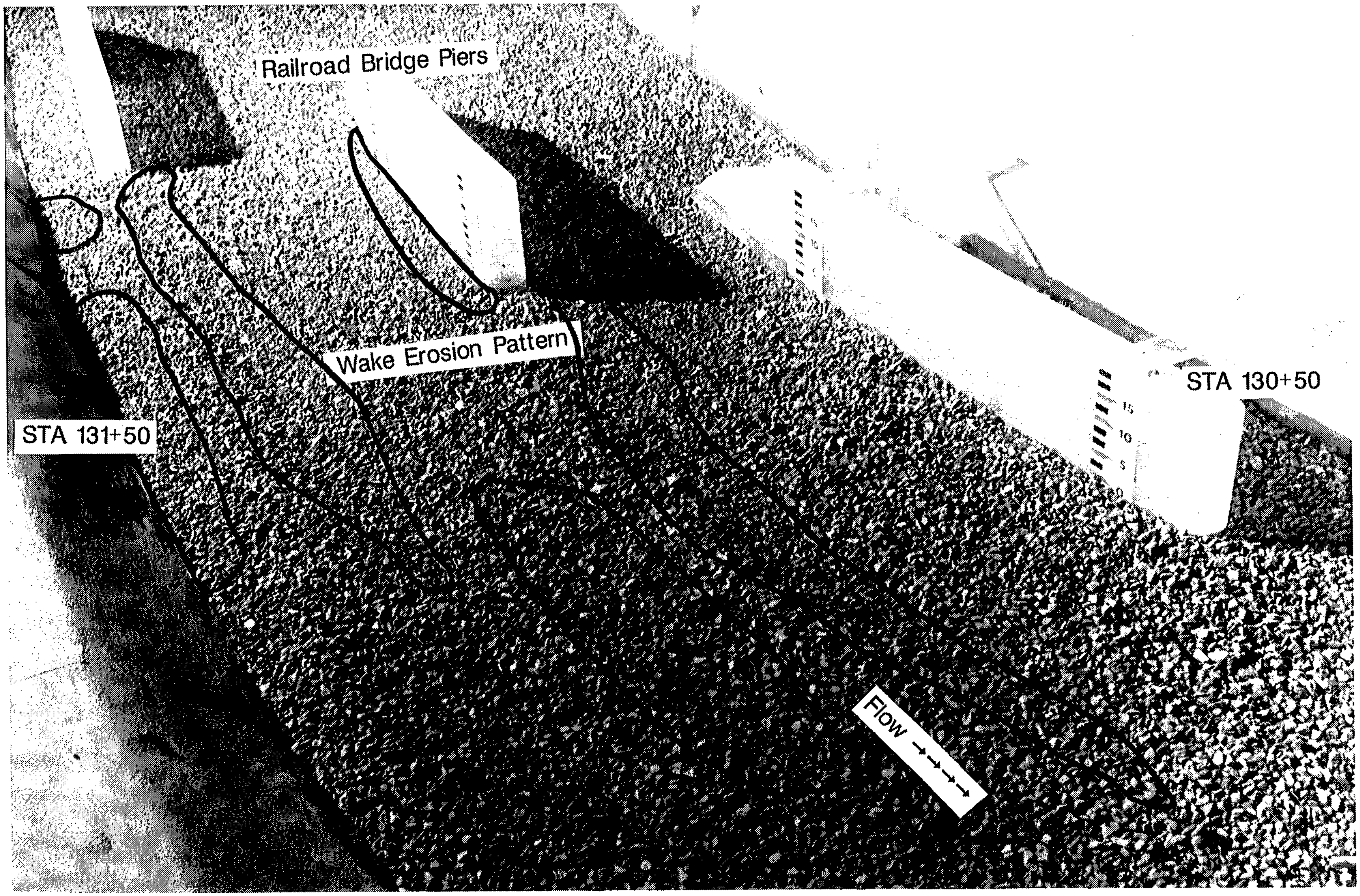


Photo 58. San Juan Creek, type 7 design, 24-hour storm hydrograph, scour analysis test, potential scour areas around railroad bridge piers

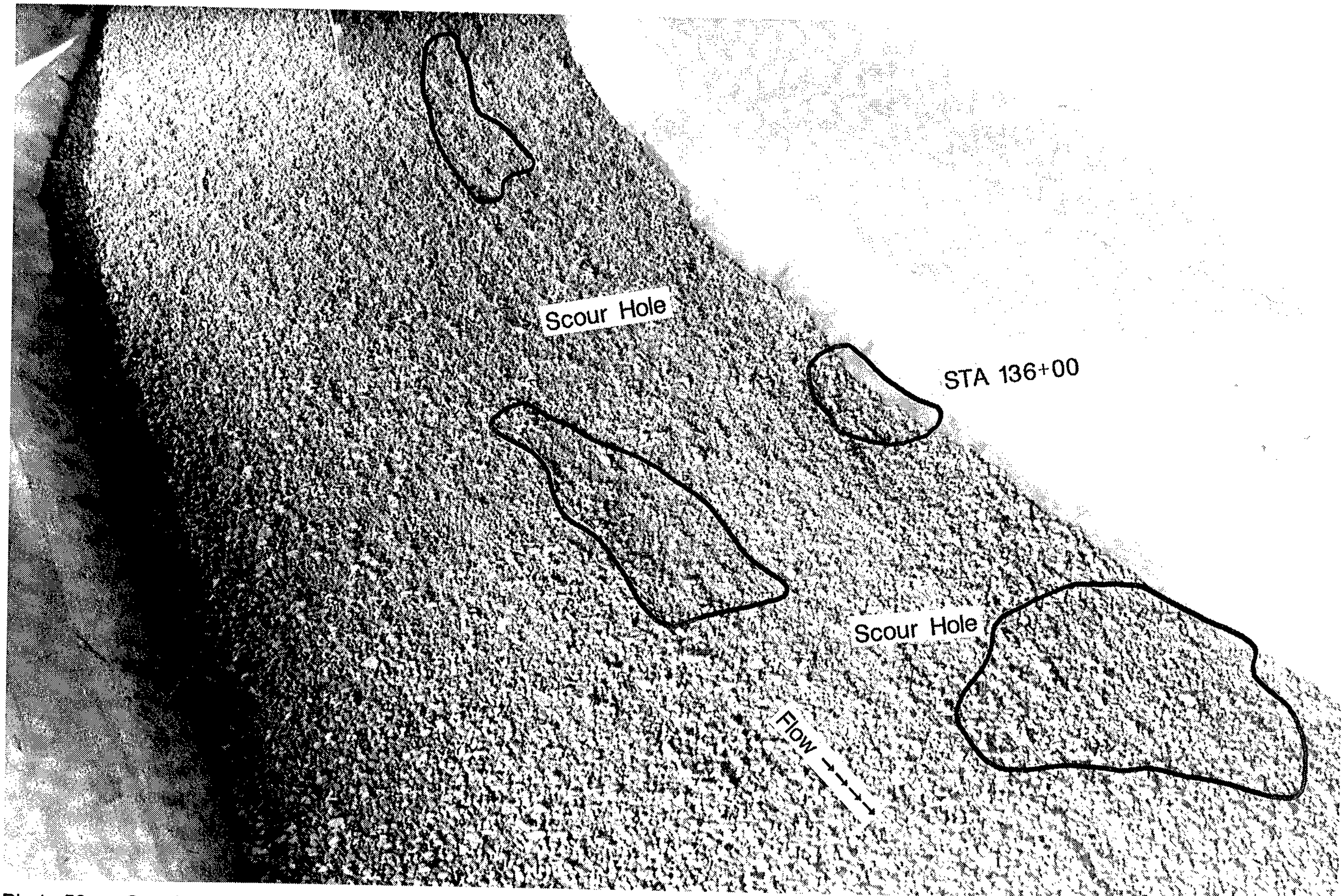


Photo 59. San Juan Creek, type 7 design, 24-hour storm hydrograph, scour analysis test, potential scour areas upstream of the railroad bridge

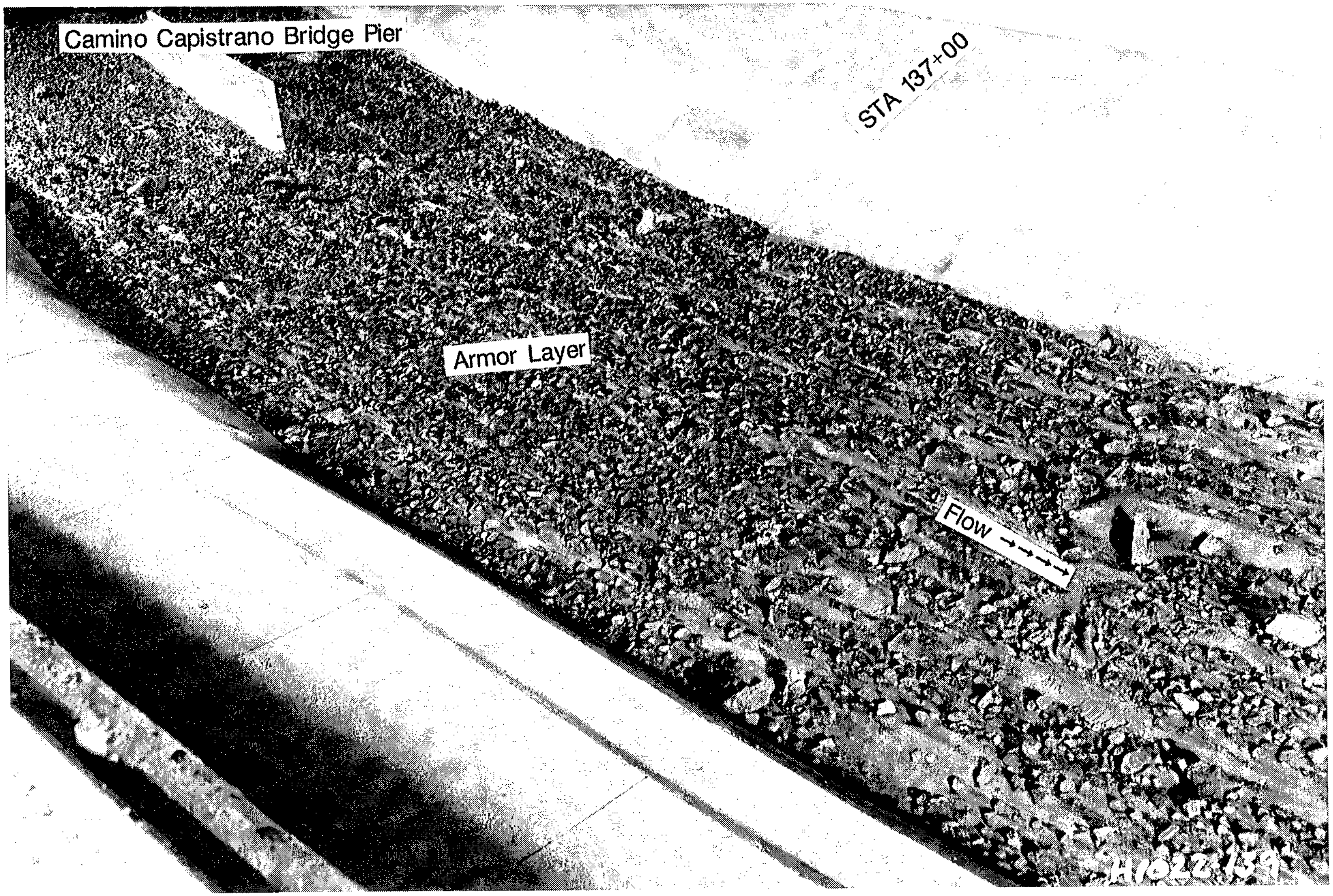


Photo 60. San Juan Creek, type 7 design, 50 percent peak, 24-hour duration, sand and gravel bed, armor layer, general degradation

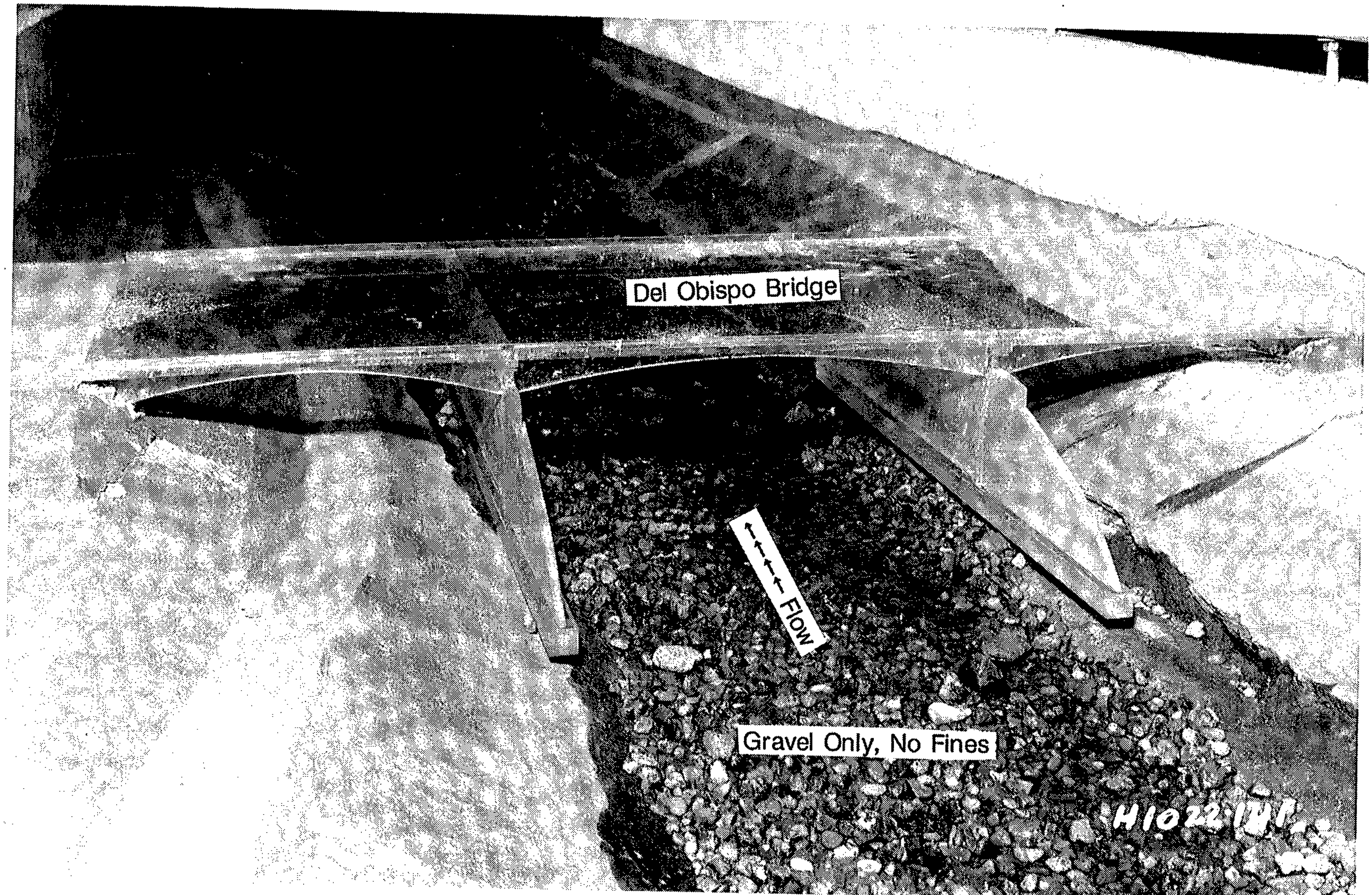


Photo 61. Trabuco Creek, type 7 design, 50 percent peak flow, 24-hour duration, Del Obispo Bridge, general degradation

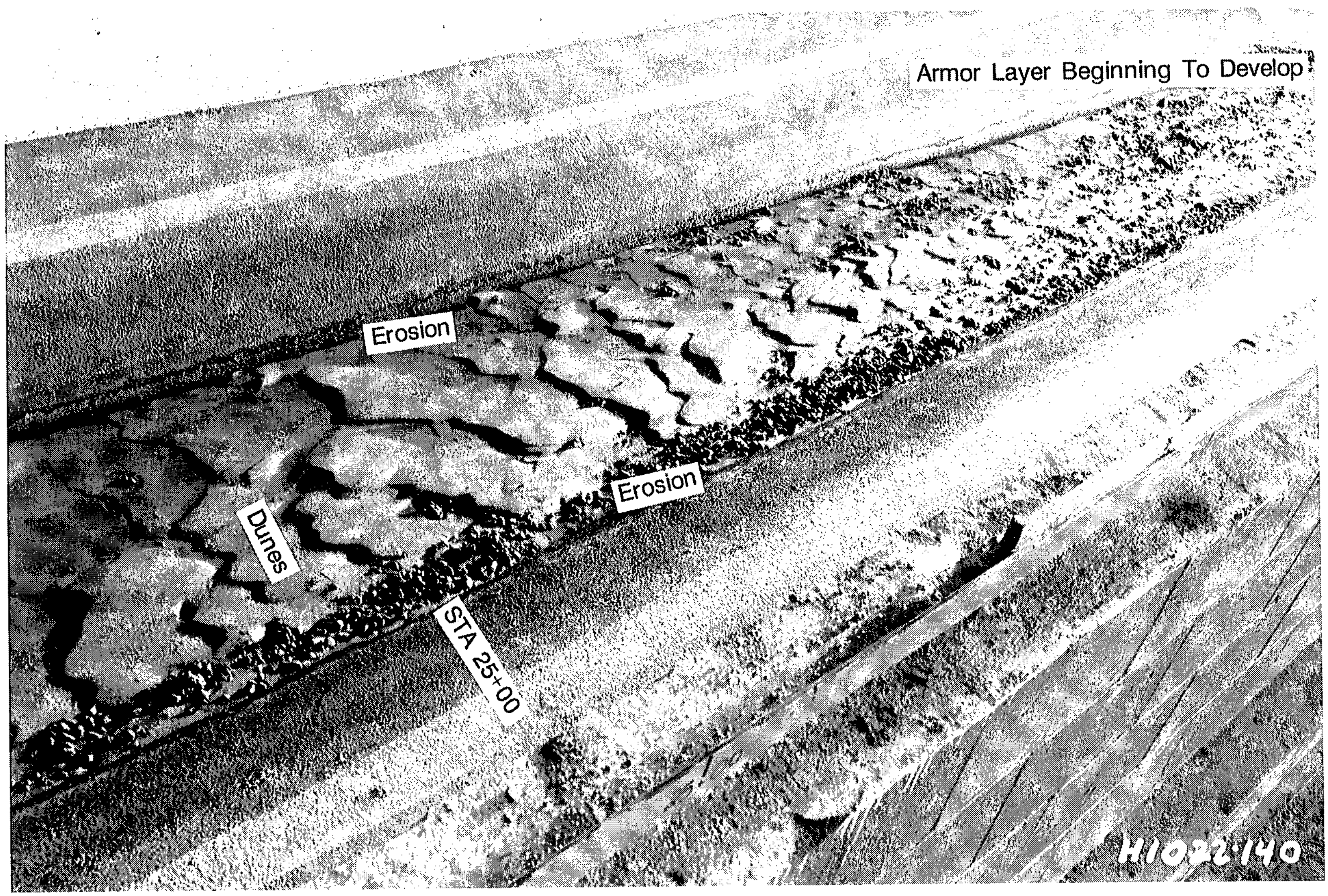


Photo 62. Trabuco Creek, type 7 design, 50 percent peak flow, 24-hour duration, scour analysis test, sand and gravel bed, dune beds with armoring

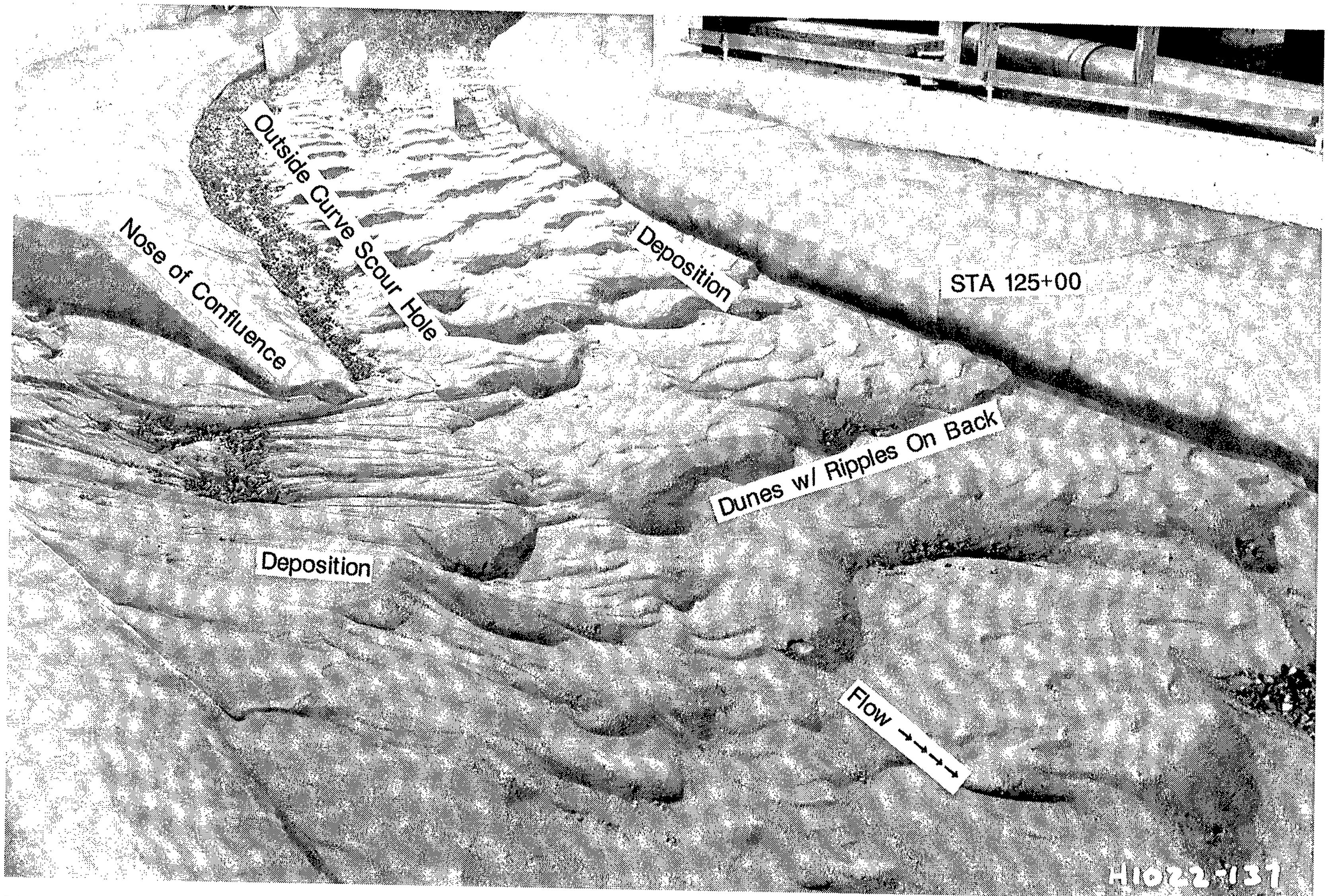


Photo 63. Confluence of San Juan and Trabuco Creeks, type 7 design, 50 percent peak flow, 24-hour duration, scour analysis test, sand and gravel bed, sand dunes with ripples on the back

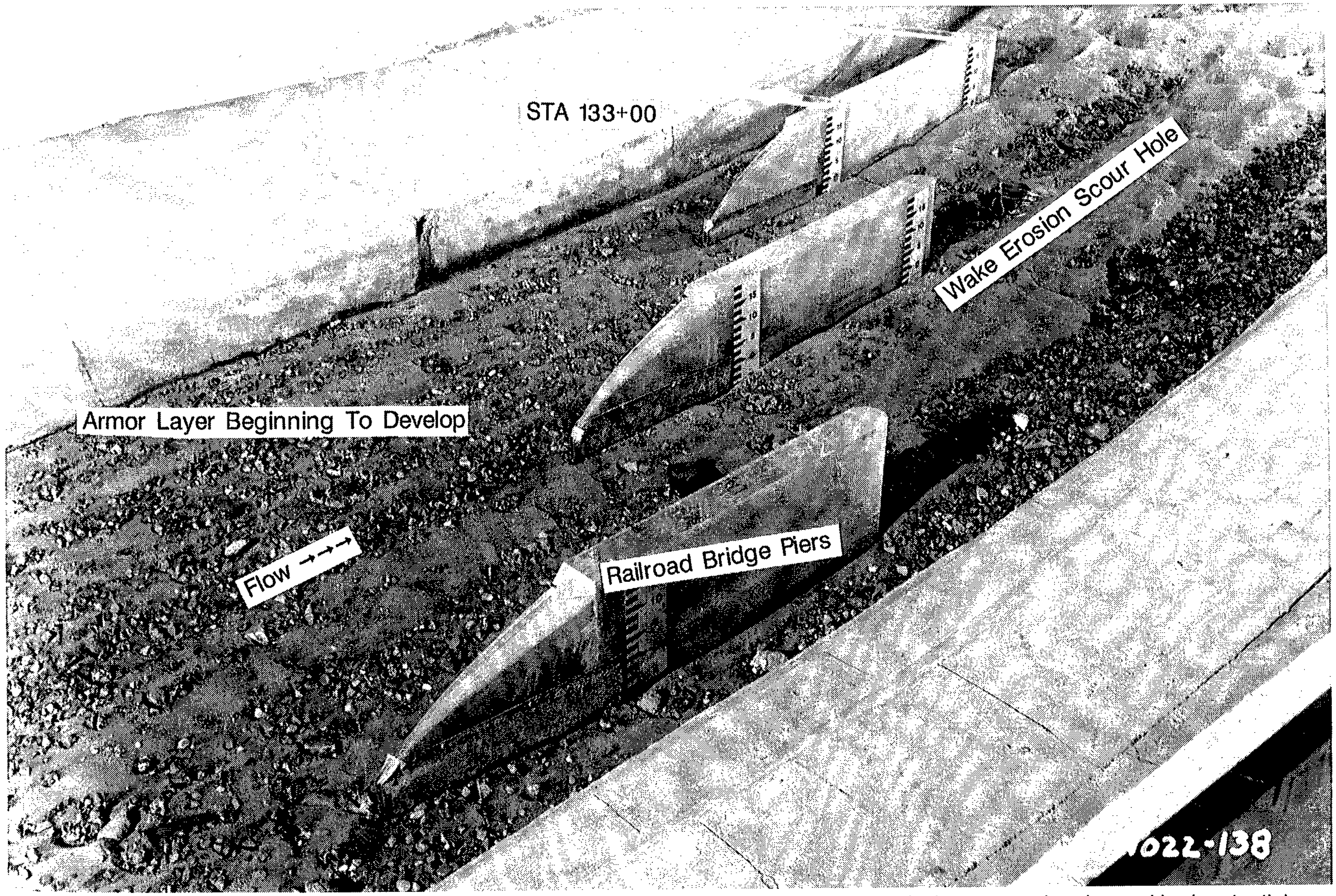
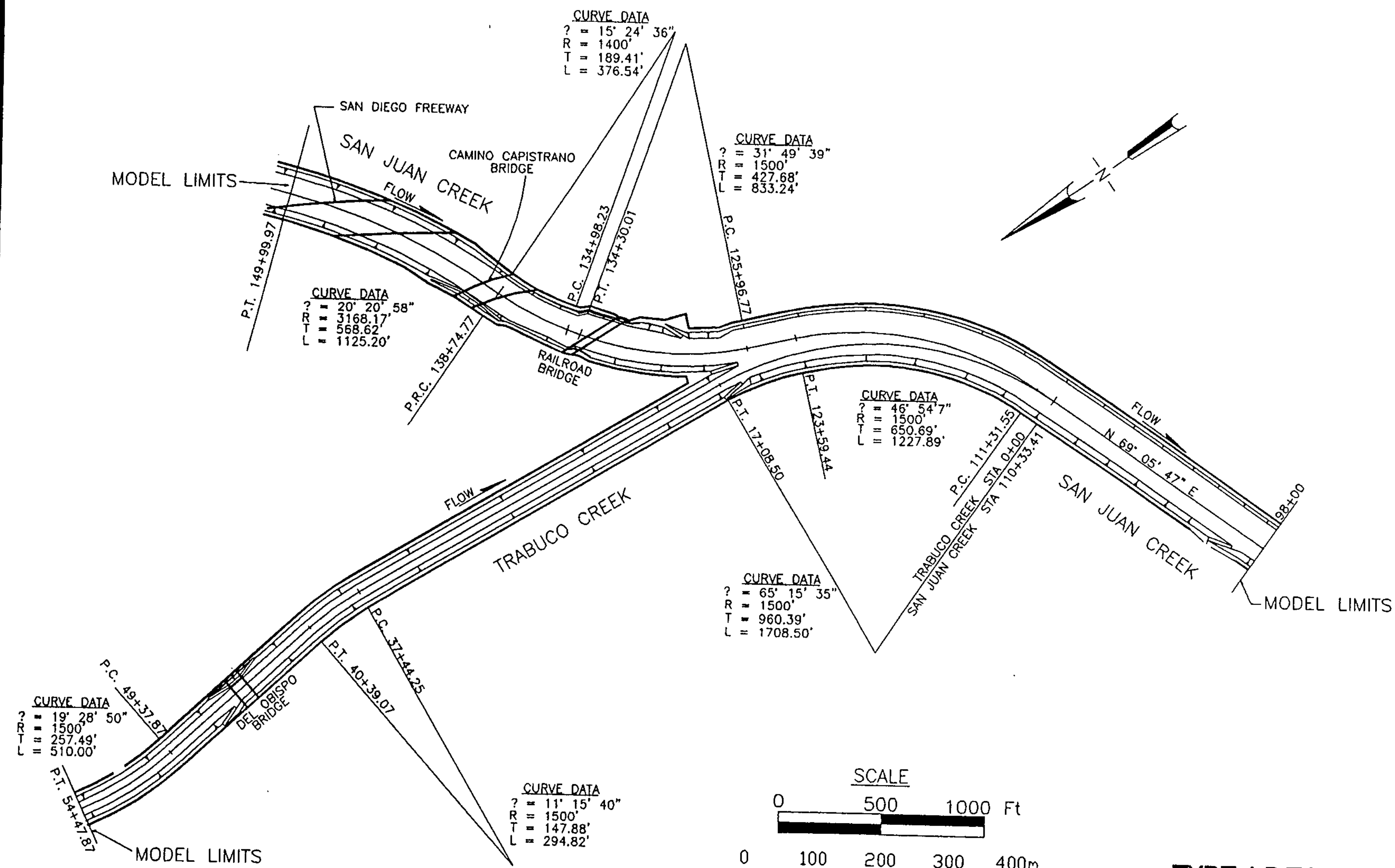


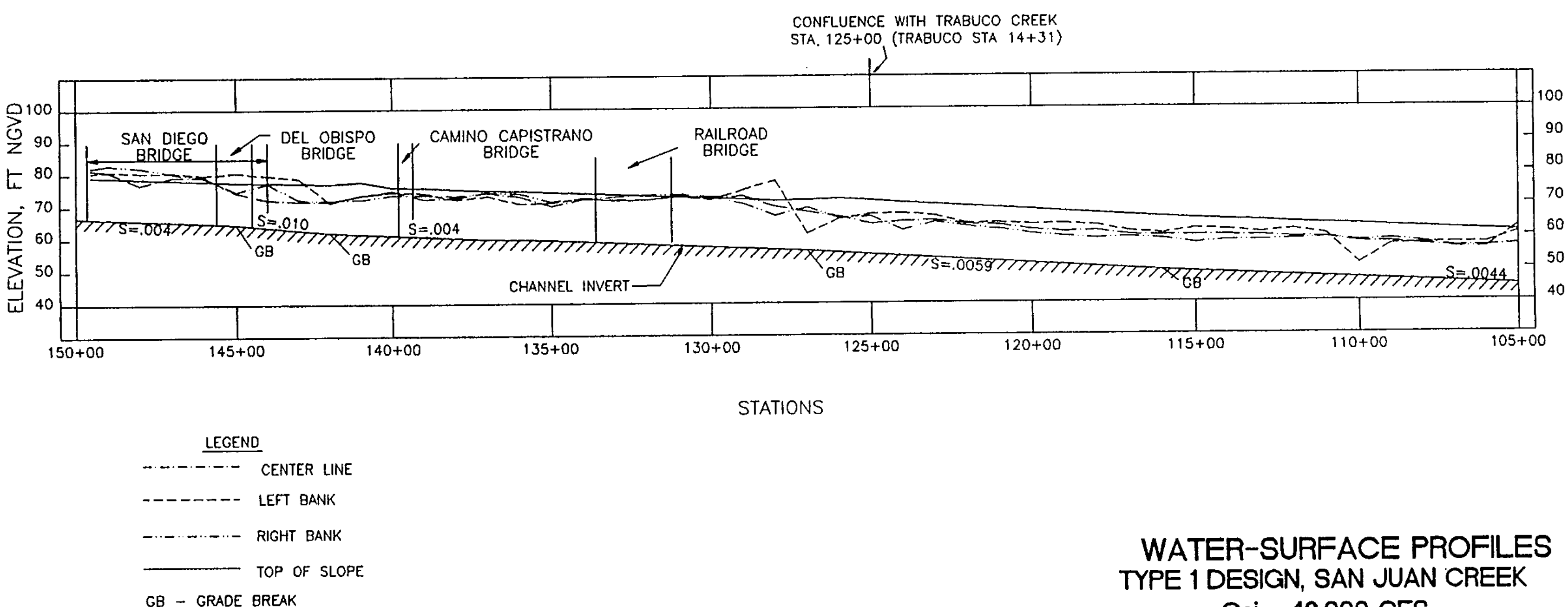
Photo 64. San Juan Creek, type 7 design, 50 percent peak flow, 24-hour duration, scour analysis test, sand and gravel bed, potential scour areas



TYPE 1 DESIGN
PLAN VIEW

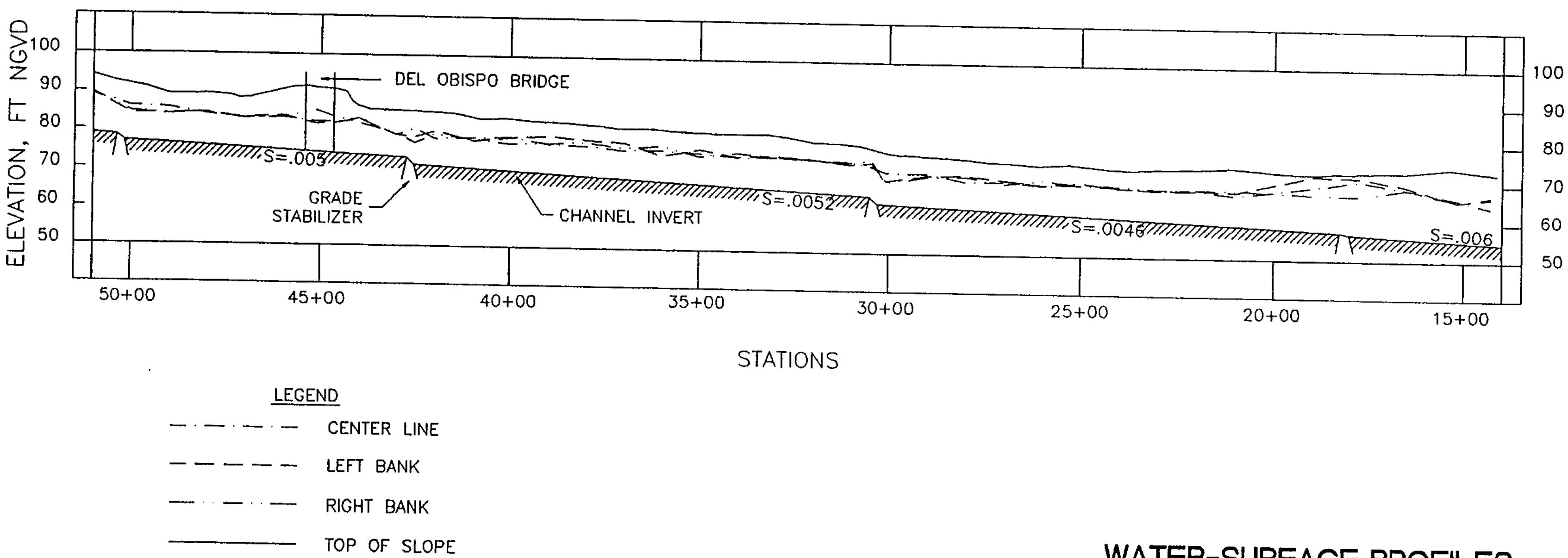
NOTE: TO CONVERT DIMENSIONS GIVEN IN FEET TO METERS, MULTIPLY BY 0.3048.

Plate 1



WATER-SURFACE PROFILES
TYPE 1 DESIGN, SAN JUAN CREEK
Qsj = 42,000 CFS
Qtr = 17,000 CFS

NOTE: TO CONVERT DIMENSIONS GIVEN IN FEET TO METERS, MULTIPLY BY 0.3048.
TO CONVERT DIMENSIONS GIVEN IN CFS TO CU M/S, MULTIPLY BY 0.0283.



NOTE: TO CONVERT DIMENSIONS GIVEN IN FEET TO METERS, MULTIPLY BY 0.3048.
TO CONVERT DIMENSIONS GIVEN IN CFS TO CU M/S, MULTIPLY BY 0.0283.

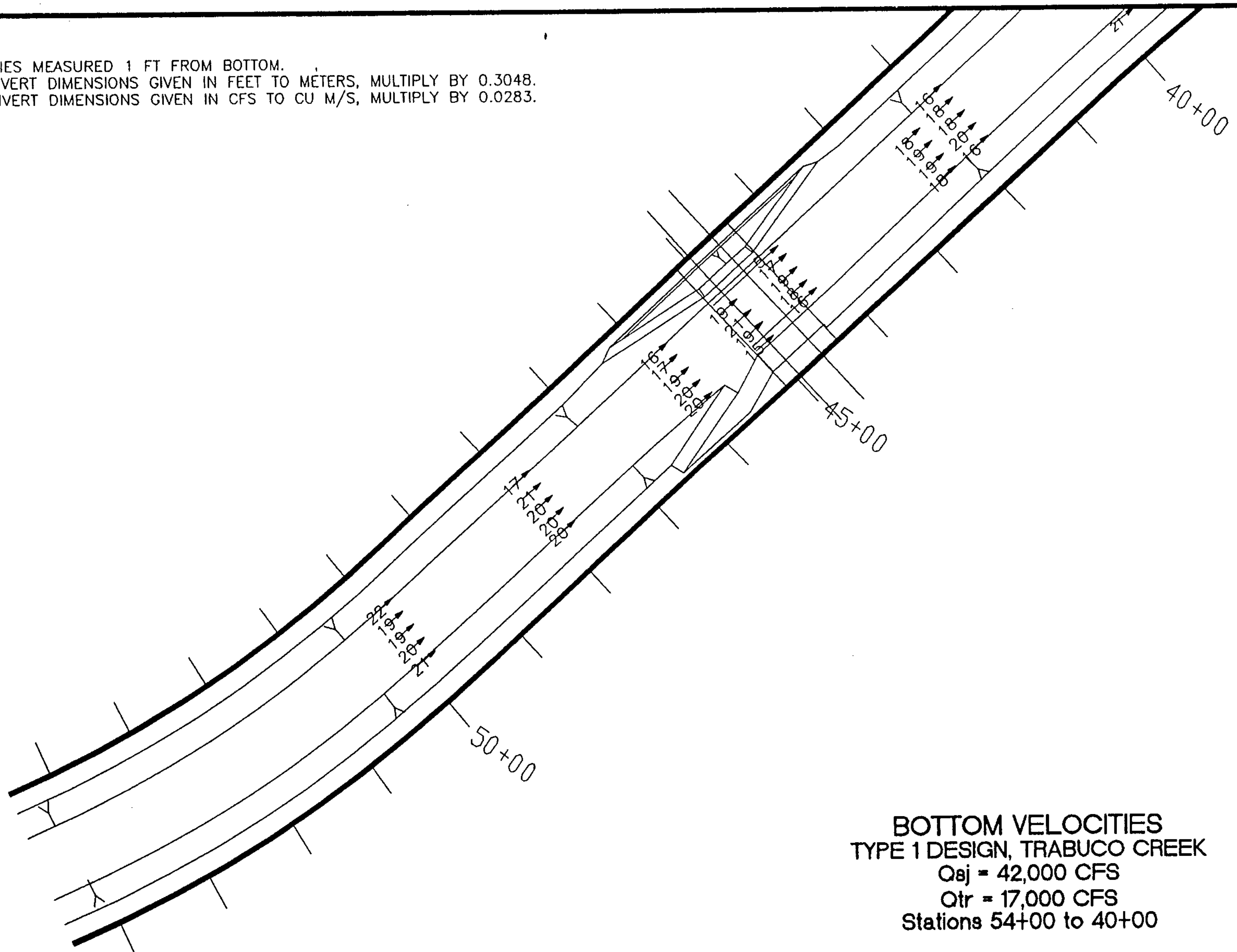
WATER-SURFACE PROFILES

TYPE 1 DESIGN, TRABUCO CREEK

Qsj = 42,000 CFS

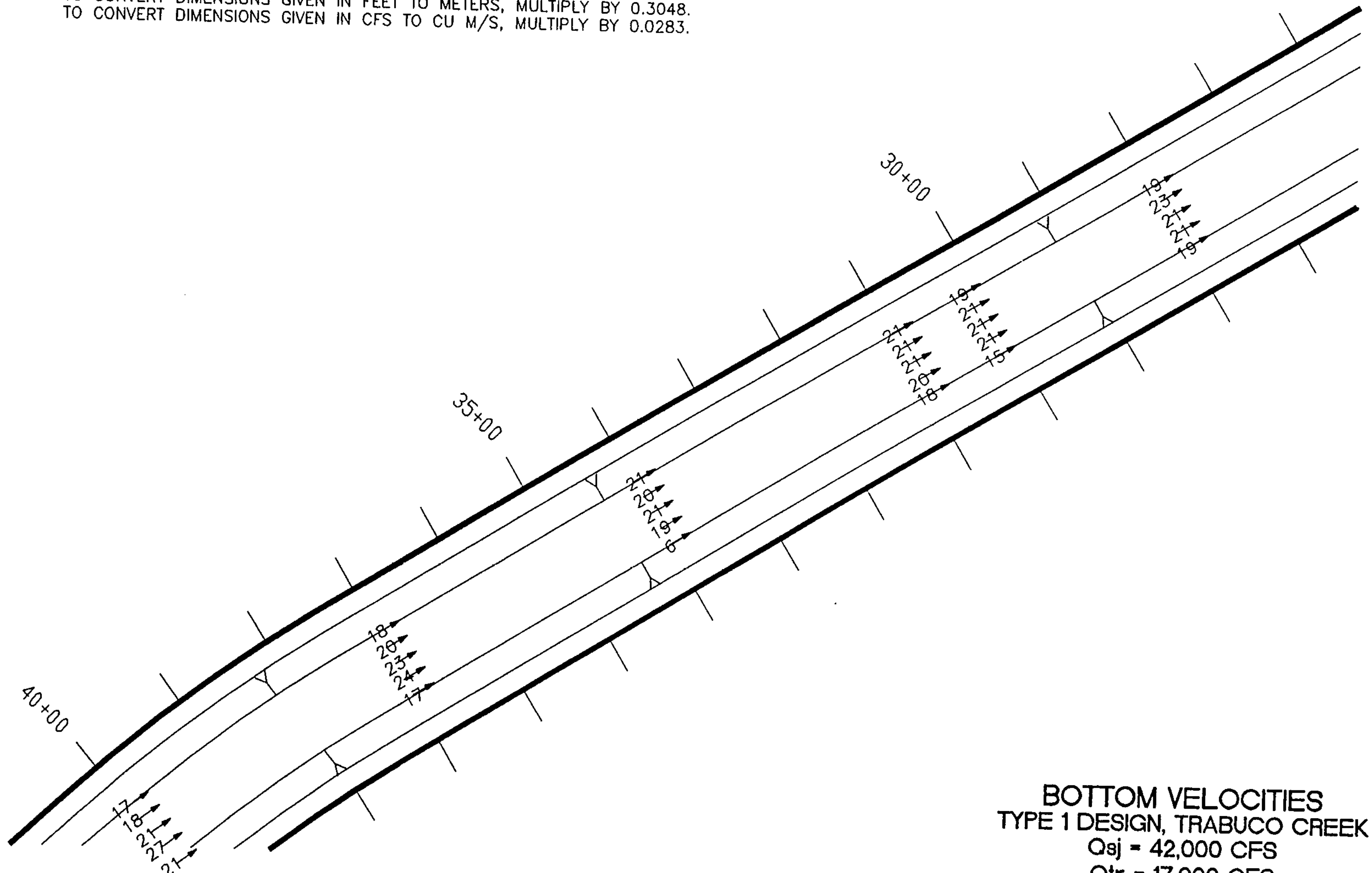
Qtr = 17,000 CFS

NOTE: VELOCITIES MEASURED 1 FT FROM BOTTOM.
TO CONVERT DIMENSIONS GIVEN IN FEET TO METERS, MULTIPLY BY 0.3048.
TO CONVERT DIMENSIONS GIVEN IN CFS TO CU M/S, MULTIPLY BY 0.0283.



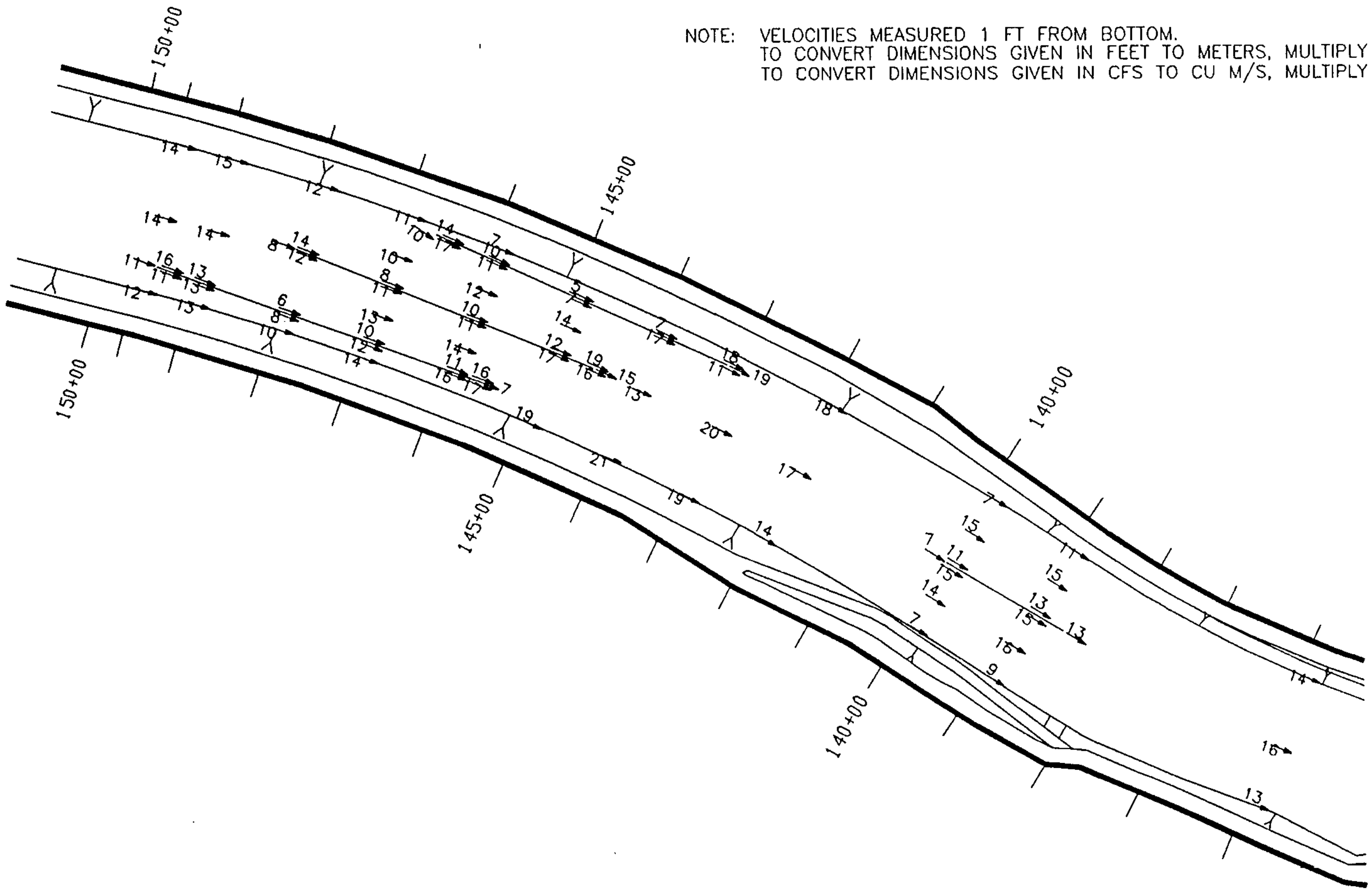
BOTTOM VELOCITIES
TYPE 1 DESIGN, TRABUCO CREEK
Qsj = 42,000 CFS
Qtr = 17,000 CFS
Stations 54+00 to 40+00

NOTE: VELOCITY MEASURED 1 FT FROM BOTTOM.
TO CONVERT DIMENSIONS GIVEN IN FEET TO METERS, MULTIPLY BY 0.3048.
TO CONVERT DIMENSIONS GIVEN IN CFS TO CU M/S, MULTIPLY BY 0.0283.

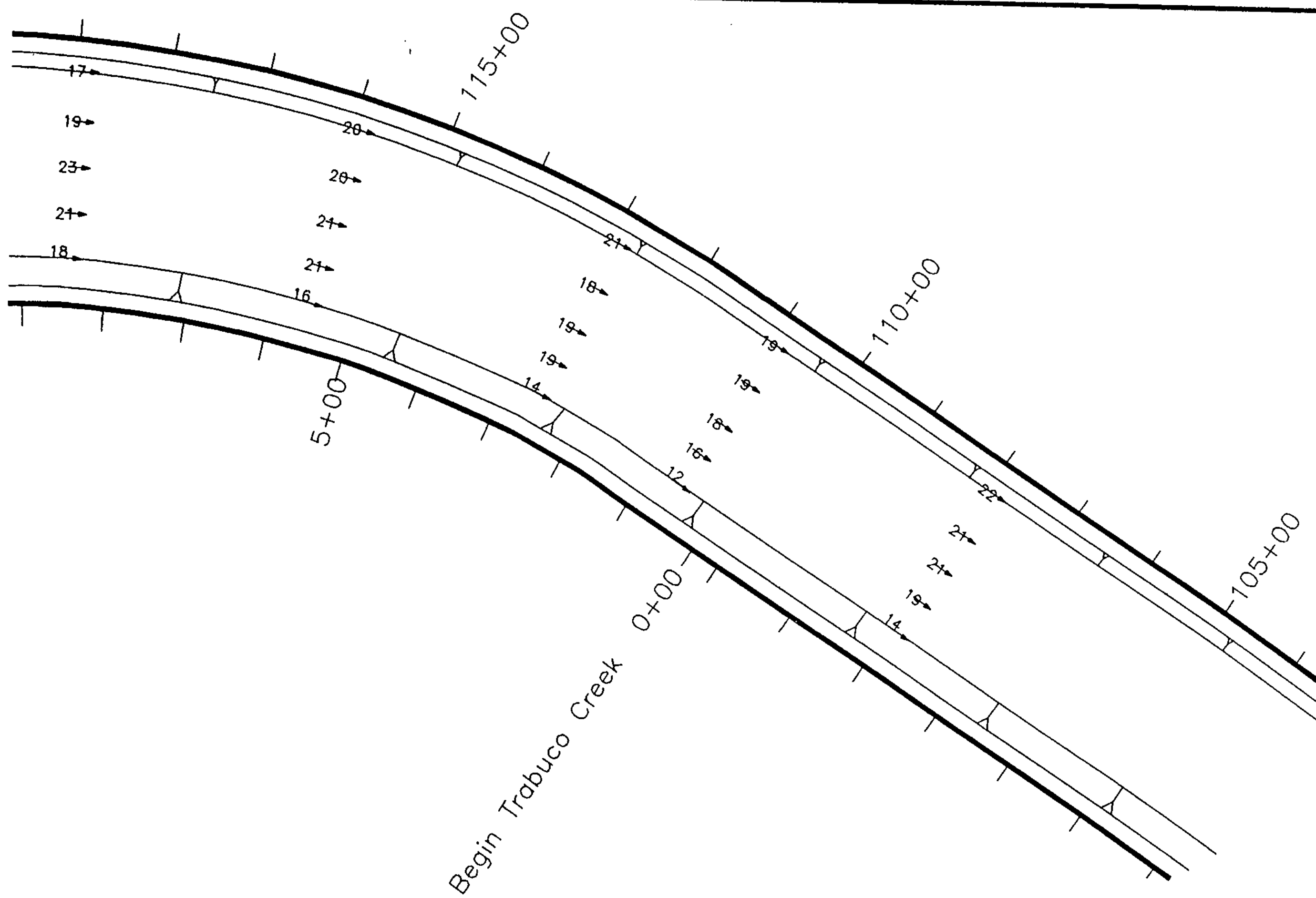


BOTTOM VELOCITIES
TYPE 1 DESIGN, TRABUCO CREEK
Qsj = 42,000 CFS
Qtr = 17,000 CFS
Stations 40+00 to 26+00

NOTE: VELOCITIES MEASURED 1 FT FROM BOTTOM.
TO CONVERT DIMENSIONS GIVEN IN FEET TO METERS, MULTIPLY BY 0.3048.
TO CONVERT DIMENSIONS GIVEN IN CFS TO CU M/S, MULTIPLY BY 0.0283.

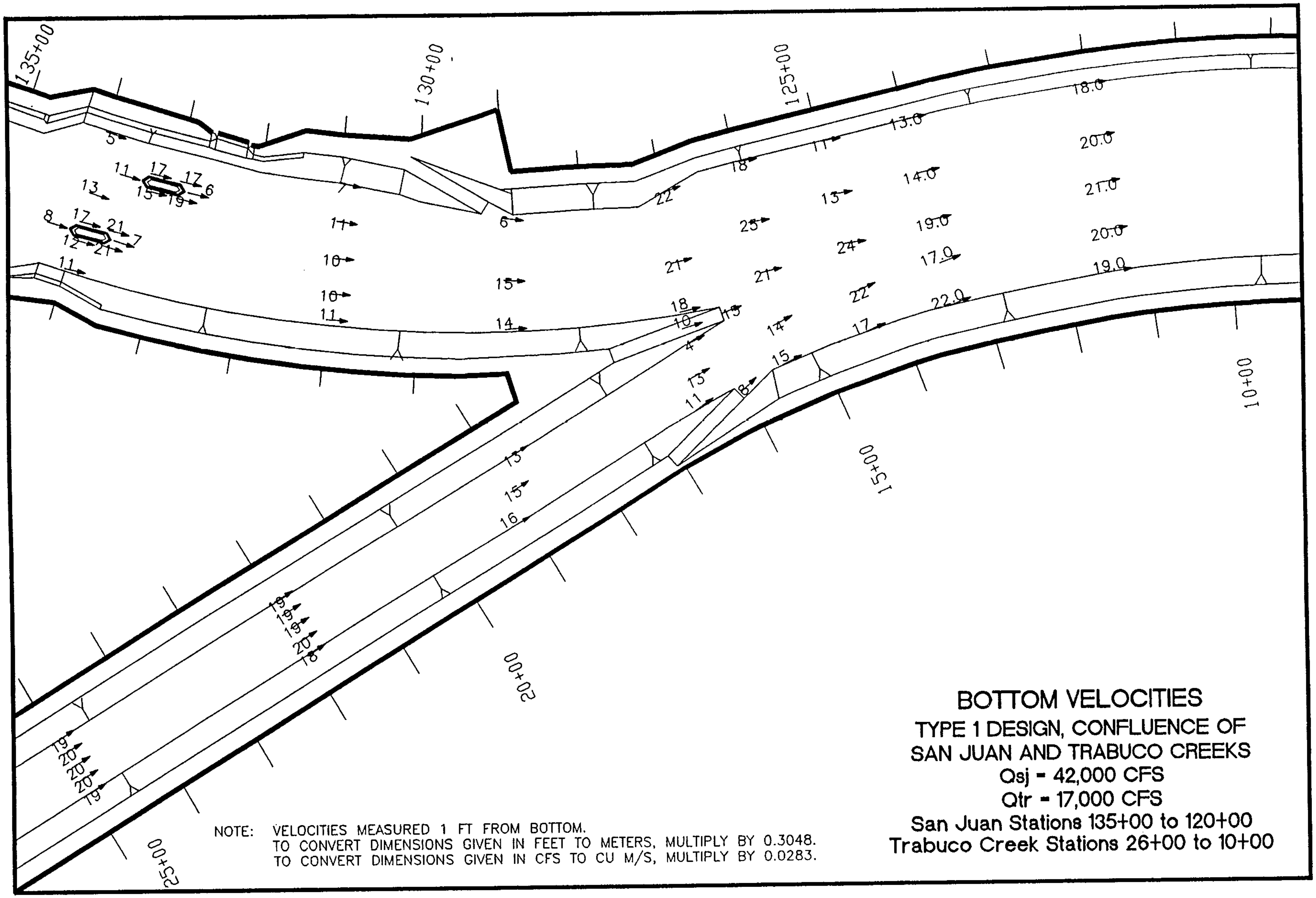


BOTTOM VELOCITIES
TYPE 1 DESIGN, SAN JUAN CREEK
Qsj = 42,000 CFS
Qtr = 17,000 CFS
Stations 150+00 to 136+00



NOTE: VELOCITY MEASURED 1 FT FROM BOTTOM.
TO CONVERT DIMENSIONS GIVEN IN FEET TO METERS, MULTIPLY BY 0.3048.
TO CONVERT DIMENSIONS GIVEN IN CFS TO CU M/S, MULTIPLY BY 0.0283.

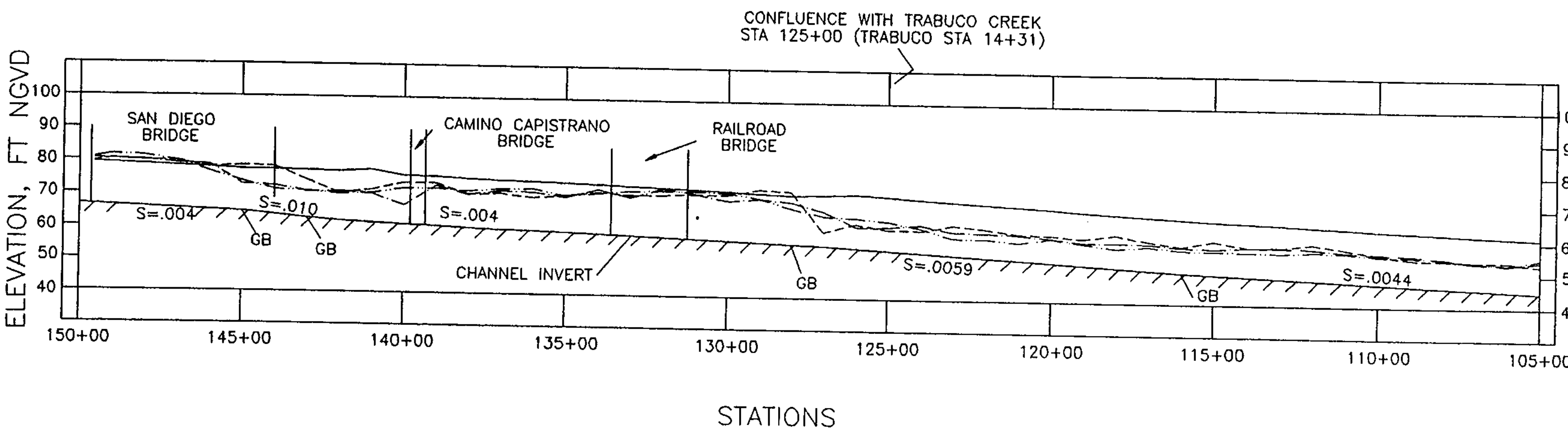
BOTTOM VELOCITIES
TYPE 1 DESIGN, SAN JUAN CREEK
Qsj = 42,000 CFS
Qtr = 17,000 CFS
Stations 119+00 to 105+00



NOTE: VELOCITIES MEASURED 1 FT FROM BOTTOM.
TO CONVERT DIMENSIONS GIVEN IN FEET TO METERS, MULTIPLY BY 0.3048.
TO CONVERT DIMENSIONS GIVEN IN CFS TO CU M/S, MULTIPLY BY 0.0283.

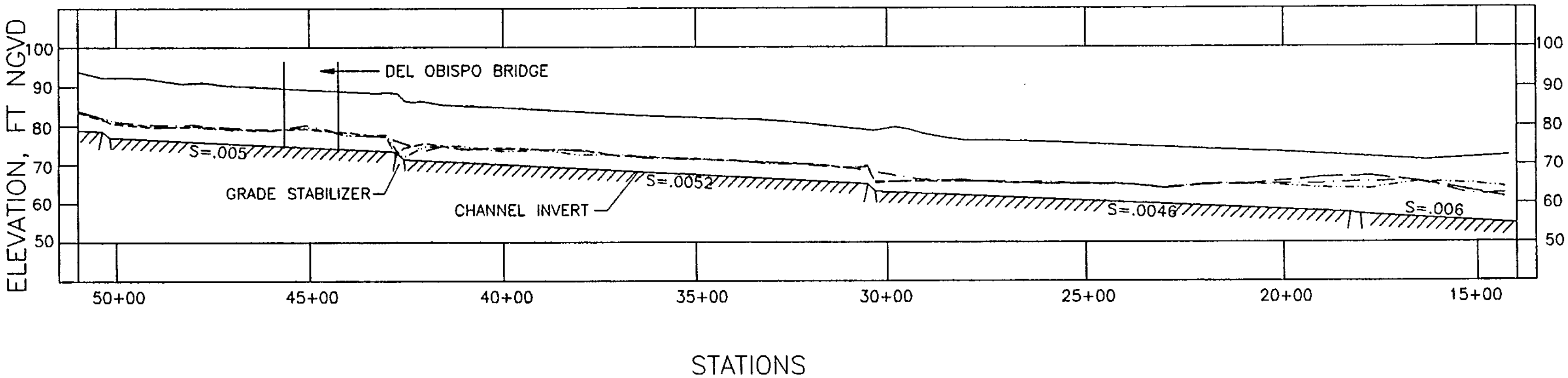
BOTTOM VELOCITIES

TYPE 1 DESIGN, CONFLUENCE OF
SAN JUAN AND TRABUCO CREEKS
Qsj = 42,000 CFS
Qtr = 17,000 CFS
San Juan Stations 135+00 to 120+00
Trabuco Creek Stations 26+00 to 10+00



NOTE: TO CONVERT DIMENSIONS GIVEN IN FEET TO METERS, MULTIPLY BY 0.3048.
TO CONVERT DIMENSIONS GIVEN IN CFS TO CU M/S, MULTIPLY BY 0.0283.

WATER-SURFACE PROFILES
TYPE 1 DESIGN, SAN JUAN CREEK
Qsj = 35,000 CFS
Qtr = 5,000 CFS

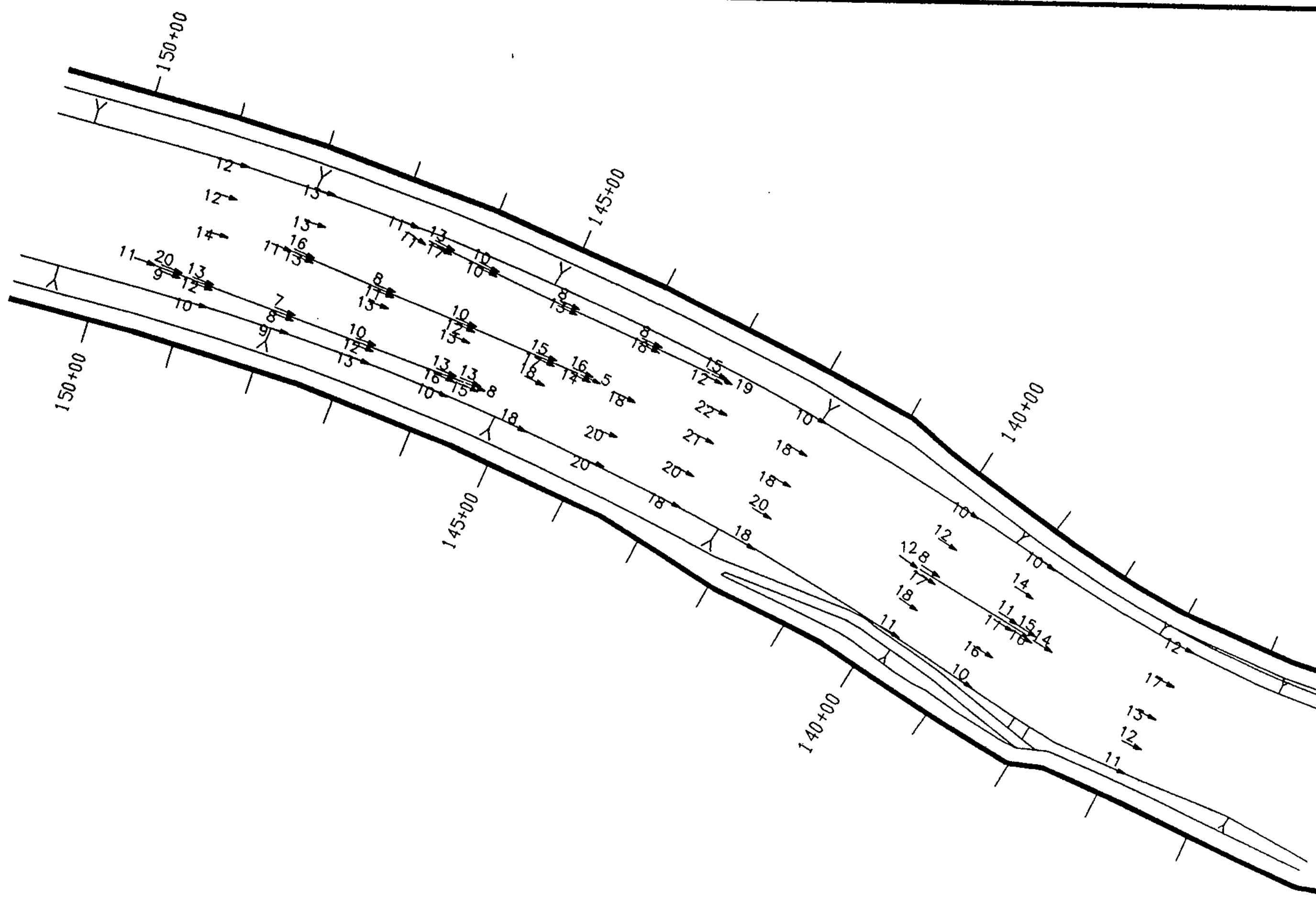


LEGEND

— · — · — CENTER LINE
— — — LEFT BANK
—··—··— RIGHT BANK
———— TOP OF SLOPE
GB – GRADE BREAK

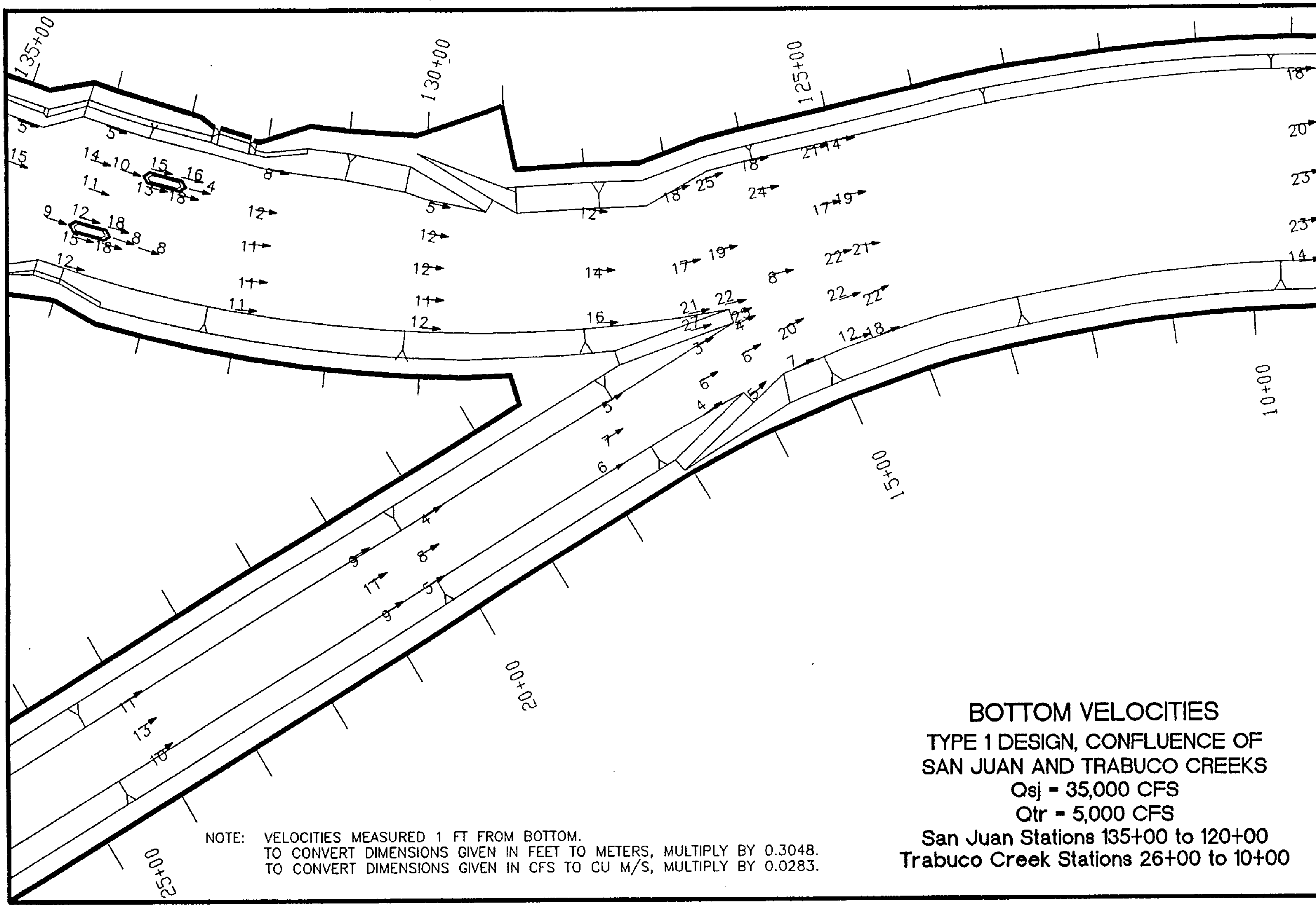
NOTE: TO CONVERT DIMENSIONS GIVEN IN FEET TO METERS, MULTIPLY BY 0.3048.
TO CONVERT DIMENSIONS GIVEN IN CFS TO CU M/S, MULTIPLY BY 0.0283.

WATER-SURFACE PROFILES
TYPE 1 DESIGN, TRABUCO CREEK
Q_{sj} = 35,000 CFS
Q_{tr} = 5,000 CFS



NOTE: VELOCITIES MEASURED 1 FT FROM BOTTOM.
TO CONVERT DIMENSIONS GIVEN IN FEET TO METERS, MULTIPLY BY 0.3048.
TO CONVERT DIMENSIONS GIVEN IN CFS TO CU M/S, MULTIPLY BY 0.0283.

BOTTOM VELOCITIES
TYPE 1 DESIGN, SAN JUAN CREEK
Qsj = 35,000 CFS
Qtr = 5,000 CFS
Stations 150+00 to 136+00

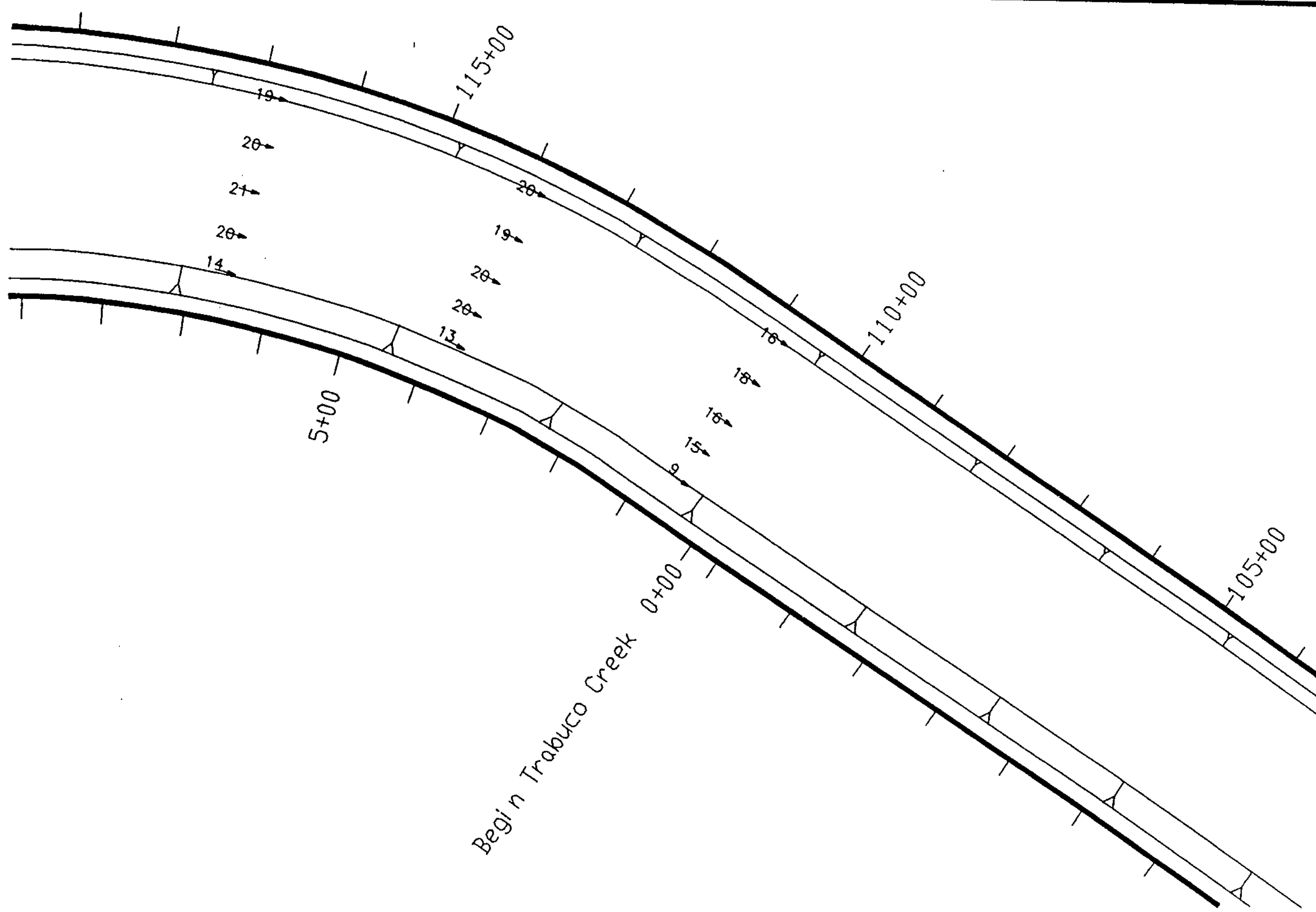


BOTTOM VELOCITIES

TYPE 1 DESIGN, CONFLUENCE OF
SAN JUAN AND TRABUCO CREEKS
Qsj = 35,000 CFS
Qtr = 5,000 CFS
San Juan Stations 135+00 to 120+00
Trabuco Creek Stations 26+00 to 10+00

NOTE: VELOCITIES MEASURED 1 FT FROM BOTTOM.
TO CONVERT DIMENSIONS GIVEN IN FEET TO METERS, MULTIPLY BY 0.3048.
TO CONVERT DIMENSIONS GIVEN IN CFS TO CU M/S, MULTIPLY BY 0.0283.

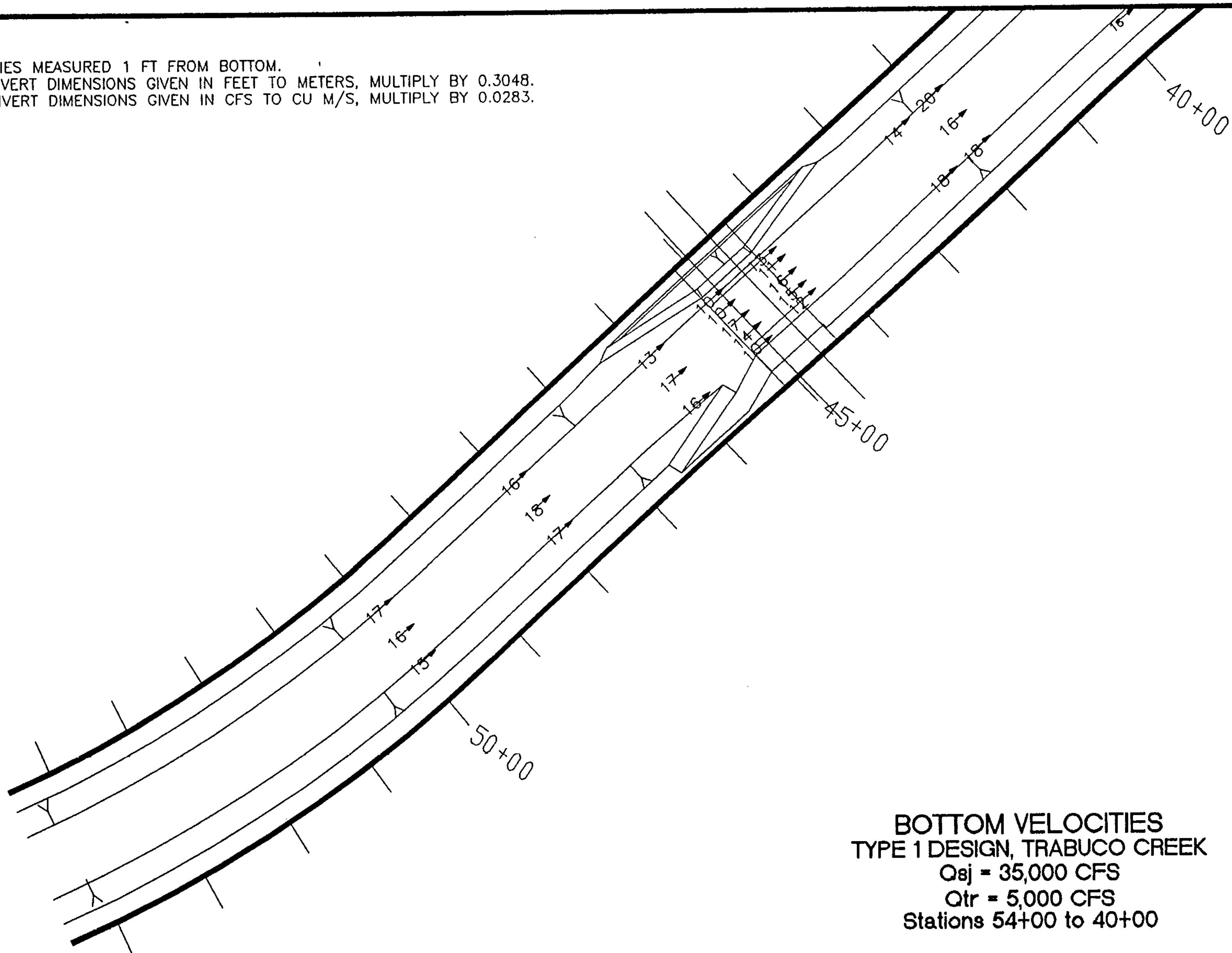
Plate 12



NOTE: VELOCITIES MEASURED 1 FT FROM BOTTOM.
TO CONVERT DIMENSIONS GIVEN IN FEET TO METERS, MULTIPLY BY 0.3048.
TO CONVERT DIMENSIONS GIVEN IN CFS TO CU M/S, MULTIPLY BY 0.0283.

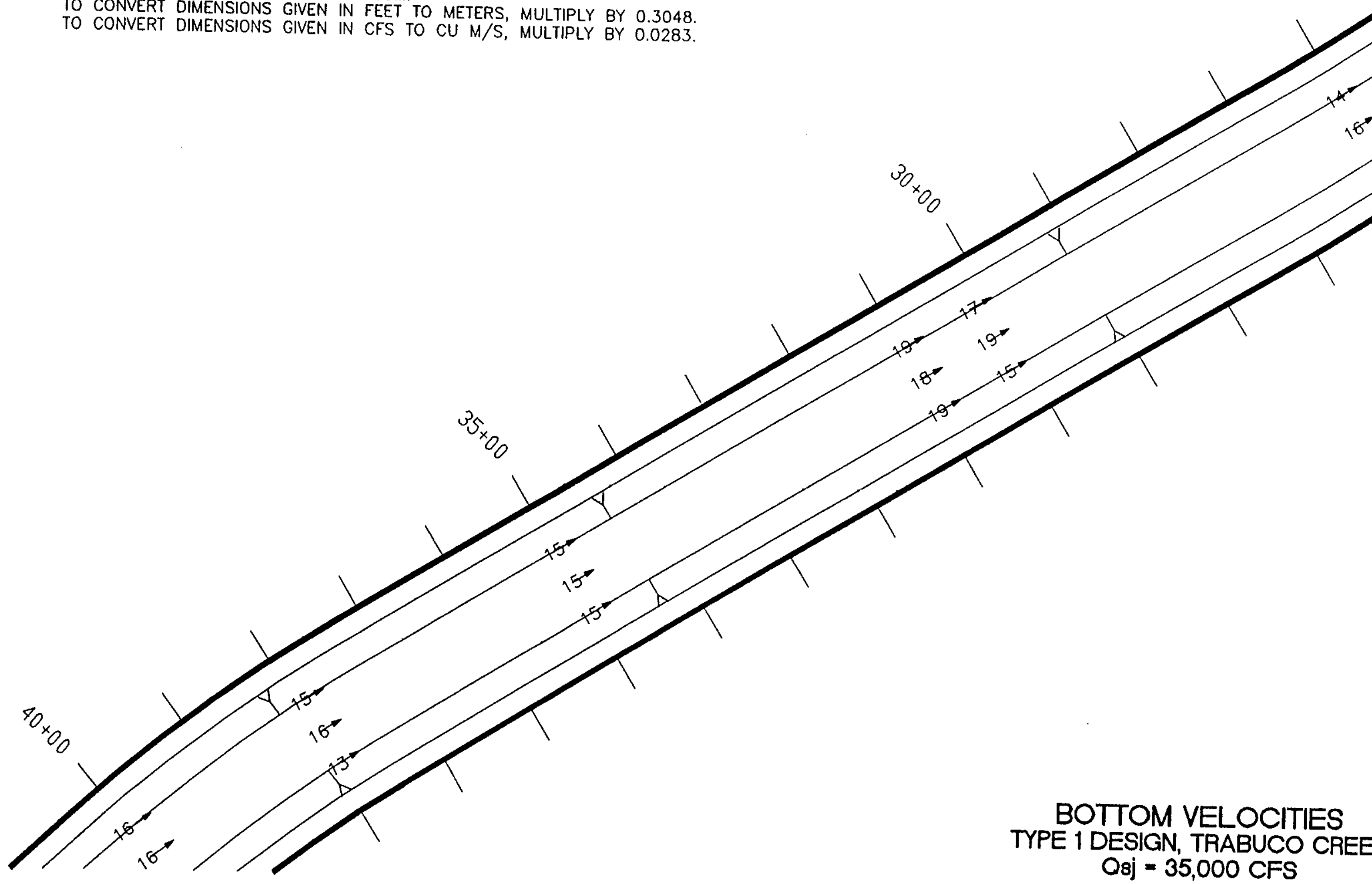
BOTTOM VELOCITIES
TYPE 1 DESIGN, SAN JUAN CREEK
Qsj = 35,000 CFS
Qtr = 5,000 CFS
Stations 119+00 to 105+00

NOTE: VELOCITIES MEASURED 1 FT FROM BOTTOM.
TO CONVERT DIMENSIONS GIVEN IN FEET TO METERS, MULTIPLY BY 0.3048.
TO CONVERT DIMENSIONS GIVEN IN CFS TO CU M/S, MULTIPLY BY 0.0283.

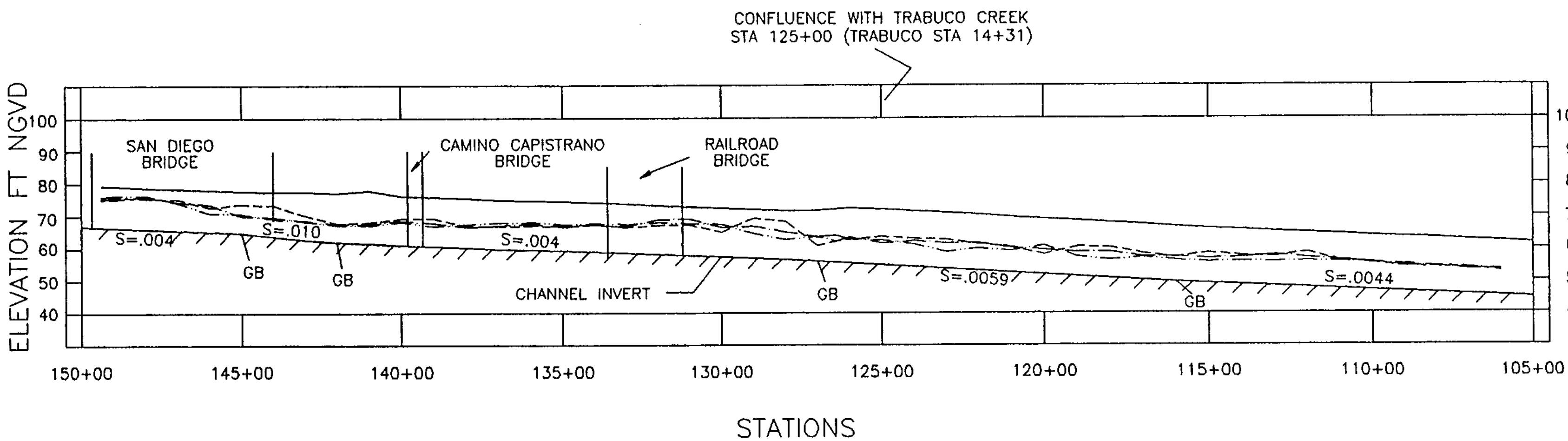


BOTTOM VELOCITIES
TYPE 1 DESIGN, TRABUCO CREEK
Qsj = 35,000 CFS
Qtr = 5,000 CFS
Stations 54+00 to 40+00

NOTE: VELOCITY MEASURED 1 FT FROM BOTTOM.
TO CONVERT DIMENSIONS GIVEN IN FEET TO METERS, MULTIPLY BY 0.3048.
TO CONVERT DIMENSIONS GIVEN IN CFS TO CU M/S, MULTIPLY BY 0.0283.



BOTTOM VELOCITIES
TYPE 1 DESIGN, TRABUCO CREEK
Qsj = 35,000 CFS
Qtr = 5,000 CFS
Stations 40+00 to 26+00



LEGEND

CENTER LINE

LEFT

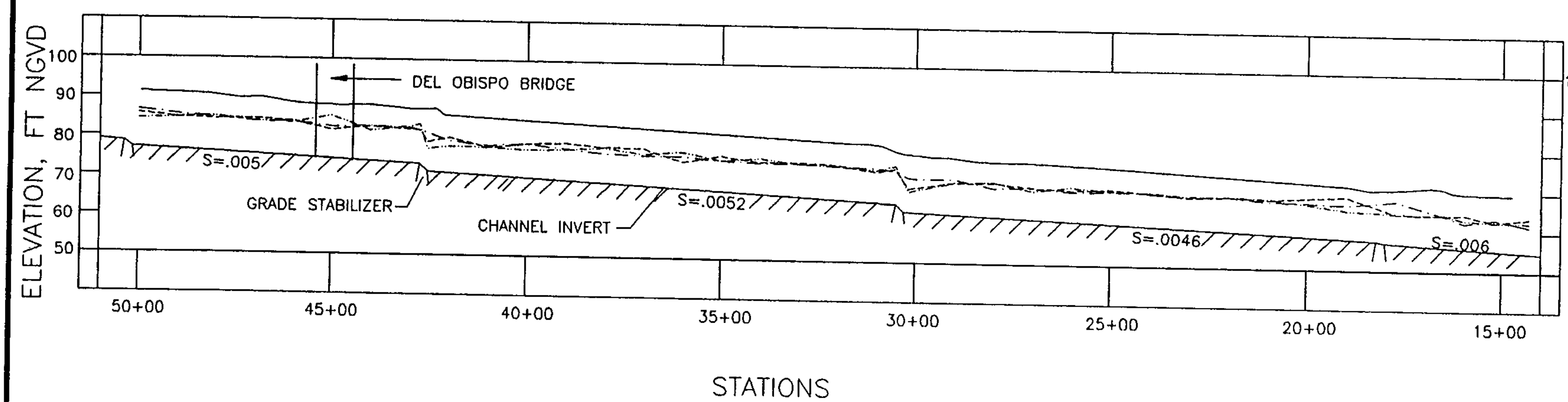
RIGHT

TOP OF SLOPE

GB – GRADE BREAK

WATER-SURFACE PROFILES
TYPE 1 DESIGN, SAN JUAN CREEK
Qsj = 17,000 CFS
Qtr = 17,000 CFS

NOTE: TO CONVERT DIMENSIONS GIVEN IN FEET TO METERS, MULTIPLY BY 0.3048.
TO CONVERT DIMENSIONS GIVEN IN CFS TO CU M/S, MULTIPLY BY 0.0283.



LEGEND
- CENTER LINE
- LEFT BANK
- RIGHT BANK
- TOP OF SLOPE

GB – GRADE BREAK

NOTE: TO CONVERT DIMENSIONS GIVEN IN FEET TO METERS, MULTIPLY BY 0.3048.
TO CONVERT DIMENSIONS GIVEN IN CFS TO CU M/S, MULTIPLY BY 0.0283.

WATER-SURFACE PROFILES
TYPE 1 DESIGN, TRABUCO CREEK
Q_{sj} = 17,000 CFS
Q_{tr} = 17,000 CFS

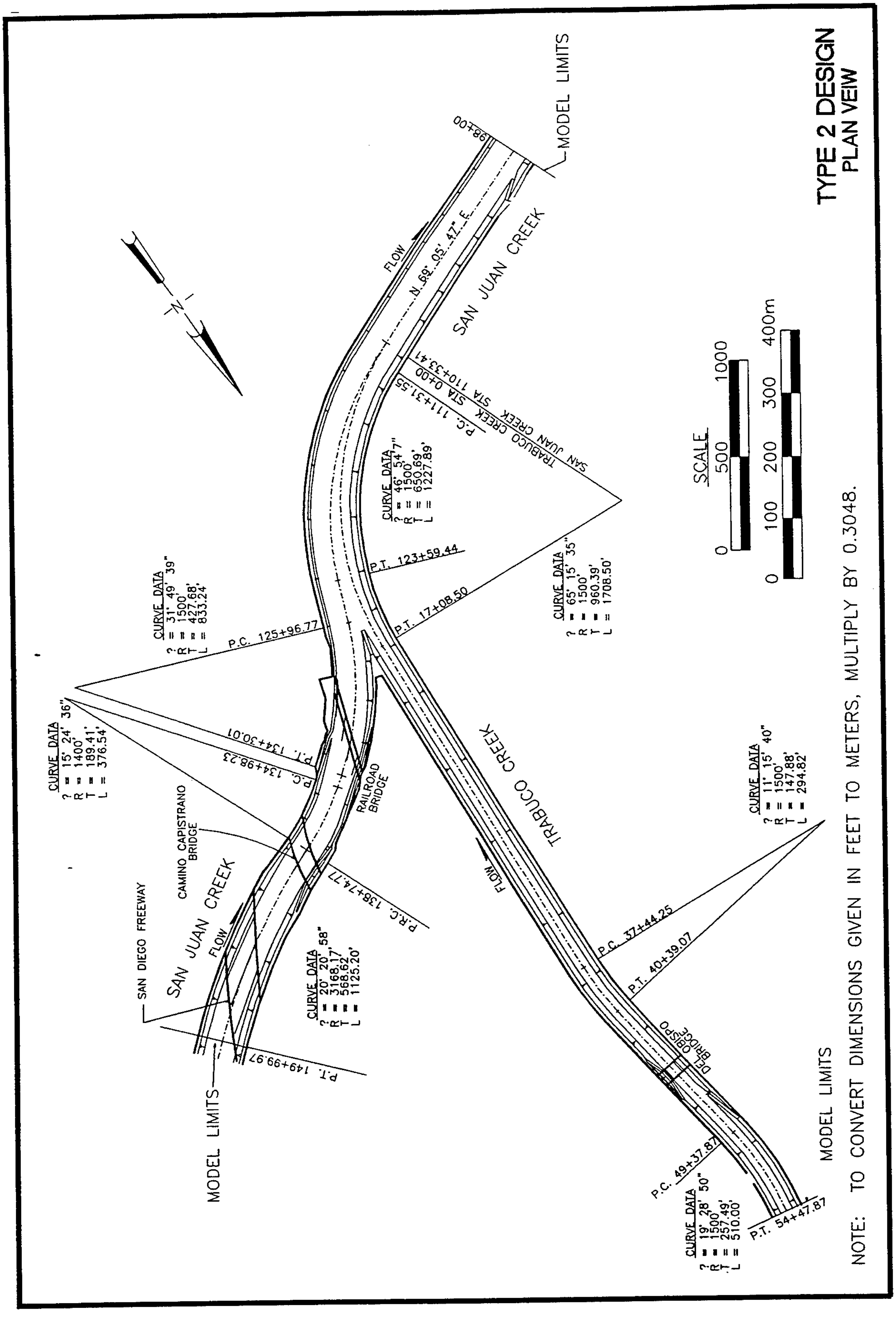
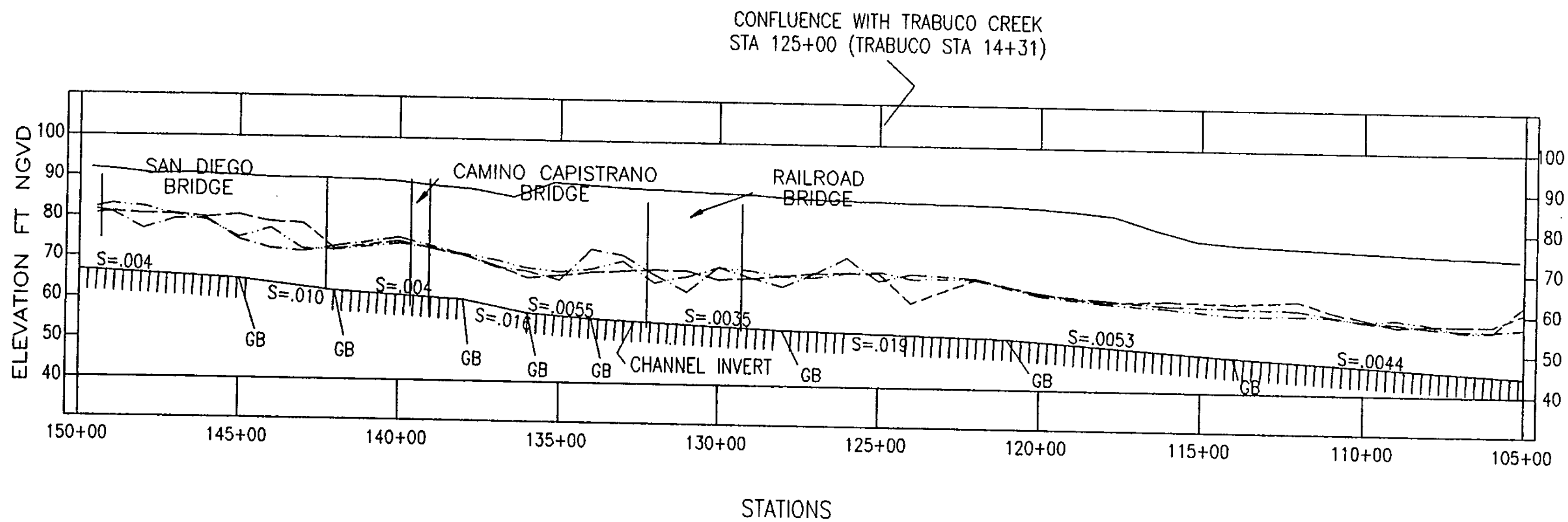

TYPE 2 DESIGN
PLAN VEIW
MODEL LIMITS
98+00
FLOW
N 69° 05' 47" E
SAN JUAN CREEK
N
P.C. 111+31.55
TRABUCO CREEK STA 0+00
SAN JUAN CREEK STA 110+33.41
CURVE DATA
? = 46° 54' 7"
R = 1500'
T = 650.69'
L = 1227.89'
P.T. 123+59.44
P.T. 17+08.50
CURVE DATA
? = 65° 15' 35"
R = 1500'
T = 960.39'
L = 1708.50'
CURVE DATA
? = 31° 49' 39"
R = 1500'
T = 427.68'
L = 833.24'
P.C. 125+96.77
CURVE DATA
? = 15° 24' 36"
R = 1400'
T = 189.41'
L = 376.54'
P.T. 134+30.01
P.C. 134+98.23
RAILROAD BRIDGE
CAMINO CAPISTRANO BRIDGE
SAN DIEGO FREEWAY
SAN JUAN CREEK
FLOW
P.R.C. 138+74.77
CURVE DATA
? = 20° 20' 58"
R = 3168.17'
T = 568.62'
L = 1125.20'
P.T. 149+99.97
MODEL LIMITS
TRABUCO CREEK
FLOW
CURVE DATA
? = 11° 15' 40"
R = 1500'
T = 147.88'
L = 294.82'
P.C. 37+44.25
P.T. 40+39.07
DEL OBISPO BRIDGE
MODEL LIMITS
P.C. 49+37.87
CURVE DATA
? = 19° 28' 50"
R = 1500'
T = 257.49'
L = 510.00'
P.T. 54+47.87
SCALE
0 500 1000
0 100 200 300 400m
NOTE: TO CONVERT DIMENSIONS GIVEN IN FEET TO METERS, MULTIPLY BY 0.3048.

Plate 18

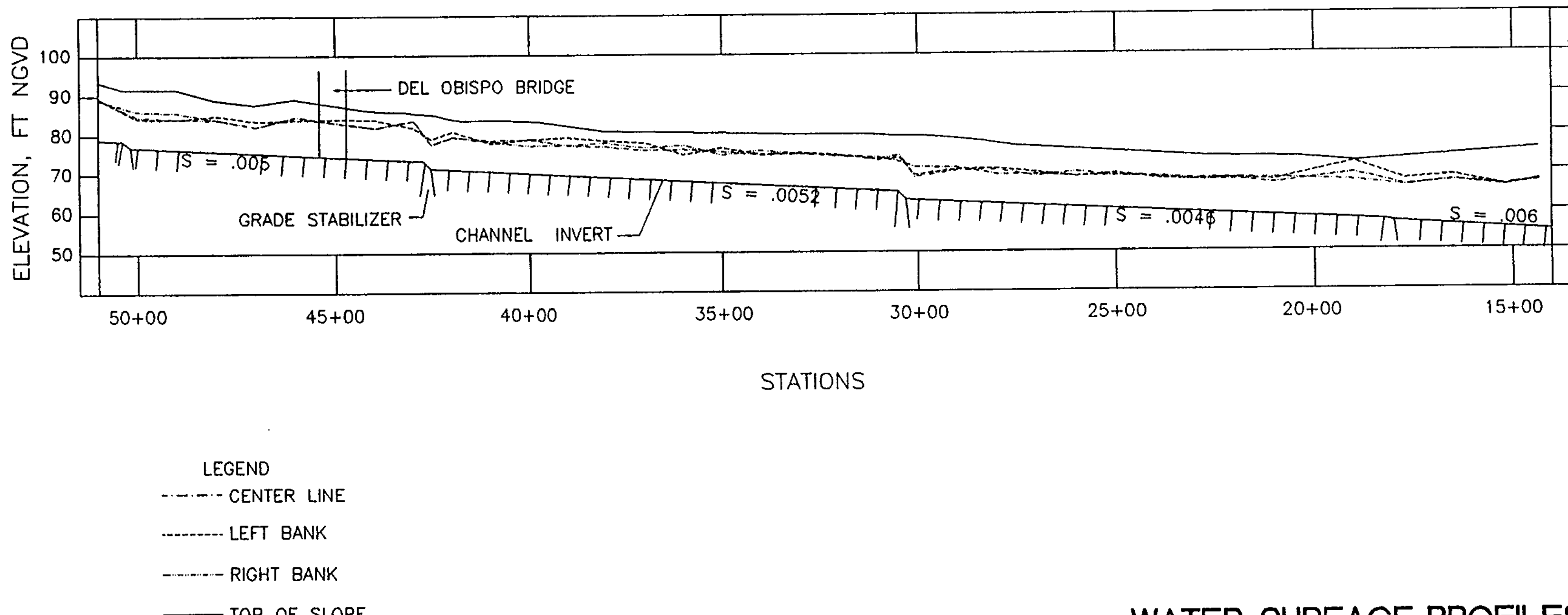


LEGEND

- —·—·— CENTER LINE
- – – – – LEFT BANK
- —··—··— RIGHT BANK
- ———— TOP OF SLOPE
- GB – GRADE BREAK

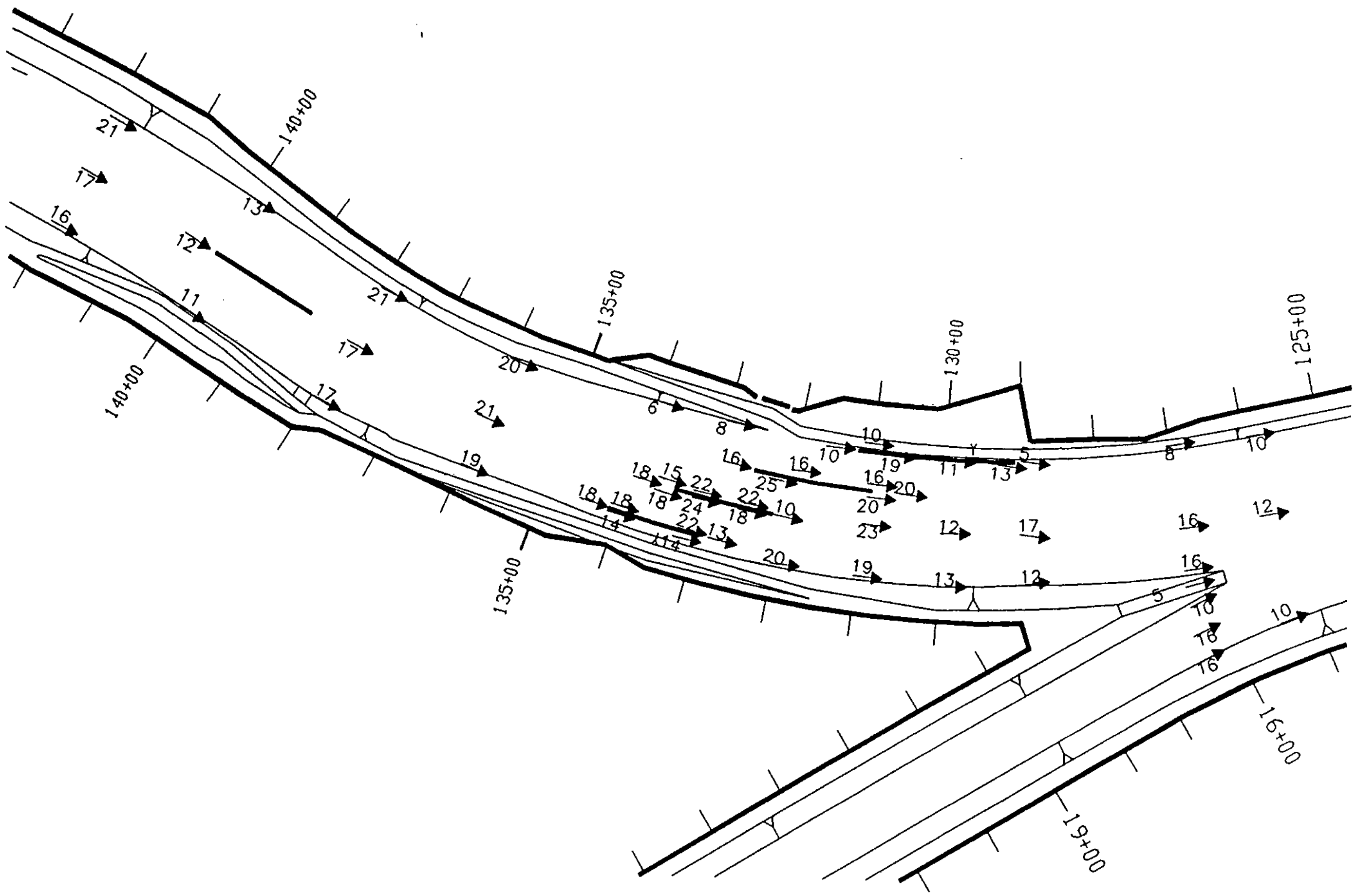
NOTE: TO CONVERT DIMENSIONS GIVEN IN FEET TO METERS, MULTIPLY BY 0.3048.
TO CONVERT DIMENSIONS GIVEN IN CFS TO CU M/S, MULTIPLY BY 0.0283.

WATER-SURFACE PROFILES
TYPE 2 DESIGN, SAN JUAN CREEK
Qsj = 42,000 CFS
Qtr = 17,000 CFS



NOTE: TO CONVERT DIMENSIONS GIVEN IN FEET TO METERS, MULTIPLY BY 0.3048.
TO CONVERT DIMENSIONS GIVEN IN CFS TO CU M/S, MULTIPLY BY 0.0283.

WATER-SURFACE PROFILES
TYPE 2 DESIGN, TRABUCO CREEK
Qsj = 42,000 CFS
Qtr = 17,000 CFS



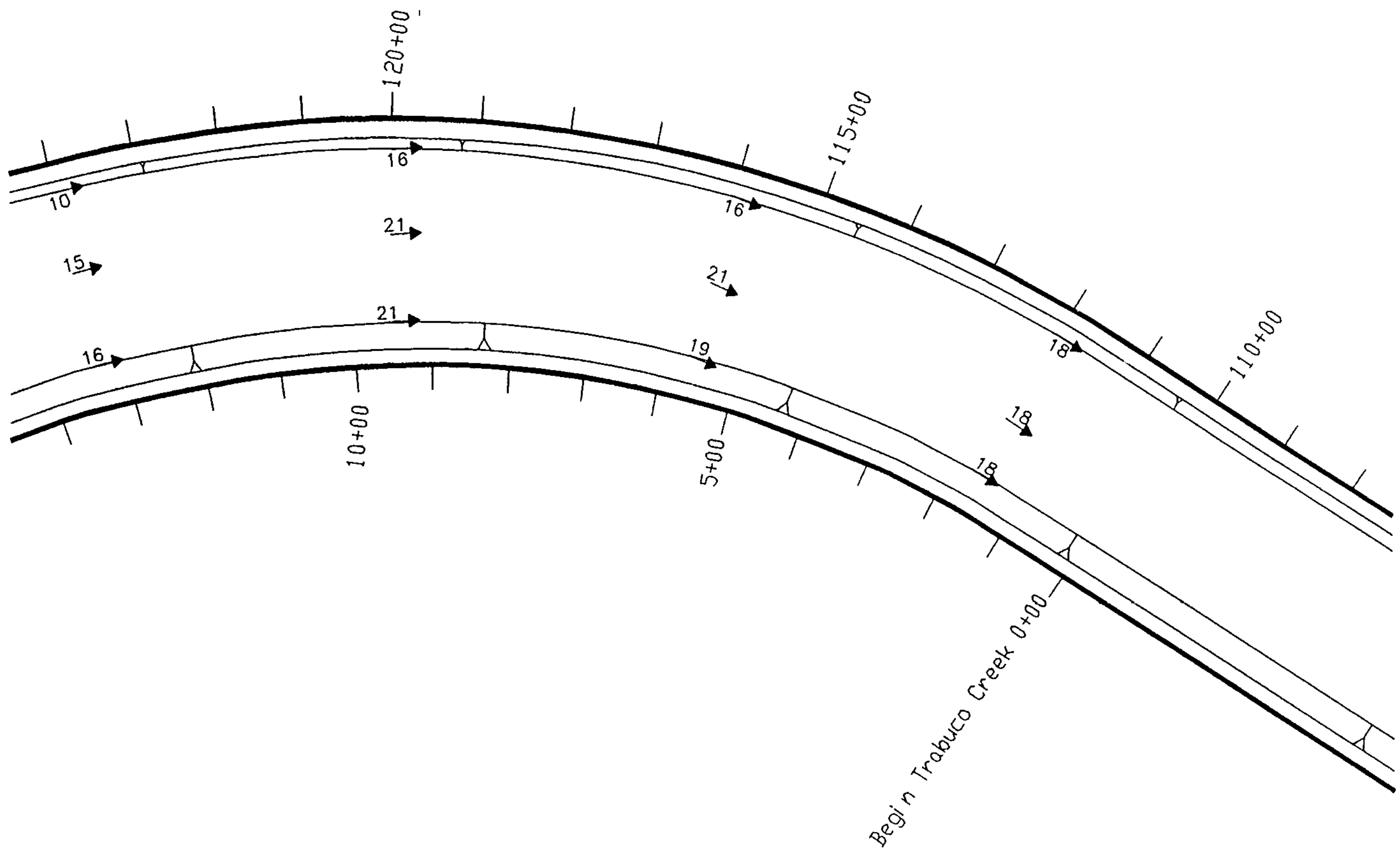
NOTE: VELOCITIES MEASURED 1 FT FROM BOTTOM.
TO CONVERT DIMENSIONS GIVEN IN FEET TO METERS, MULTIPLY BY 0.3048.
TO CONVERT DIMENSIONS GIVEN IN CFS TO CU M/S, MULTIPLY BY 0.0283.

BOTTOM VELOCITIES

TYPE 2 DESIGN, CONFLUENCE OF SAN JUAN AND TRABUCO CREEKS

Qsj - 42,000 CFS

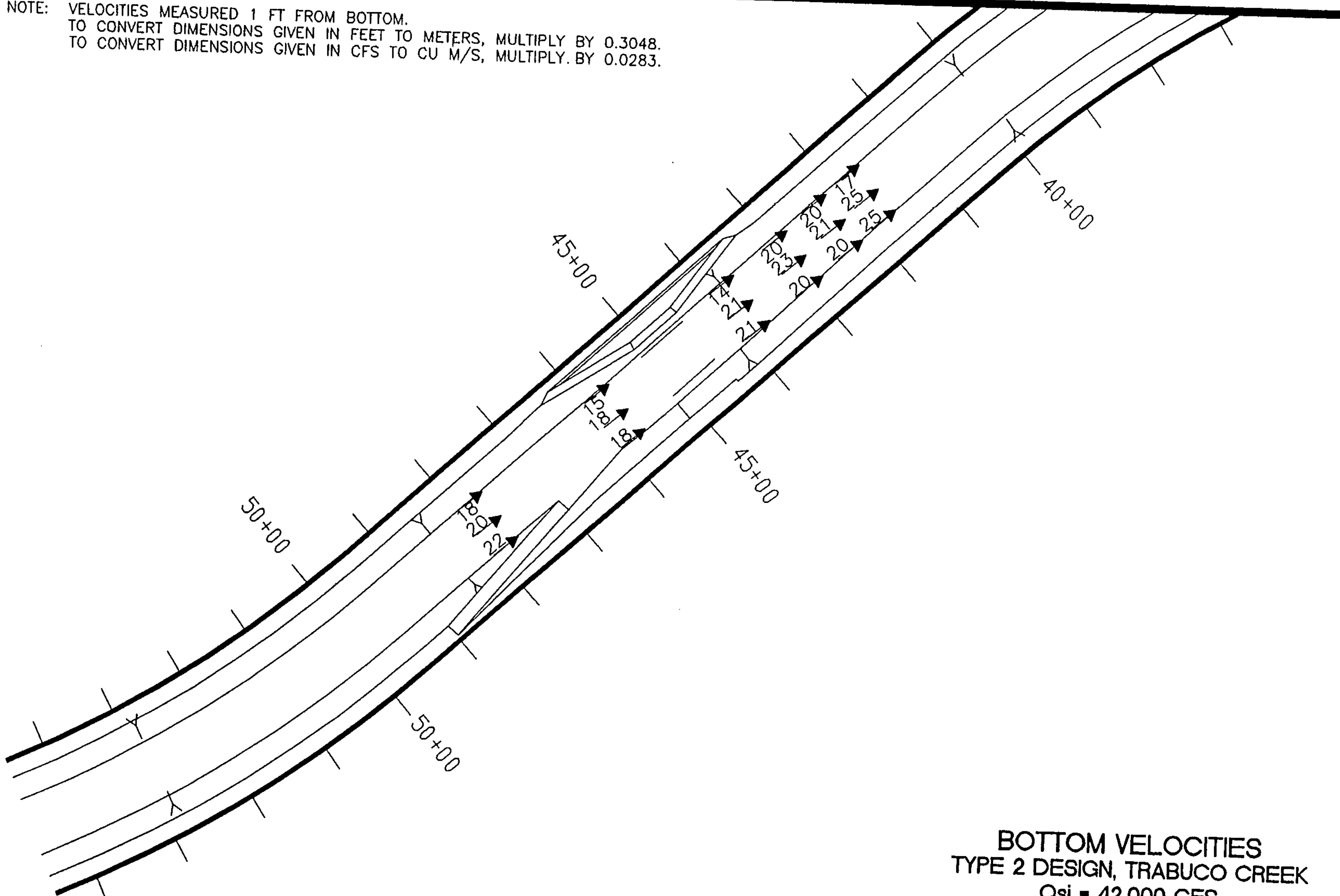
Qtr - 17,000 CFS



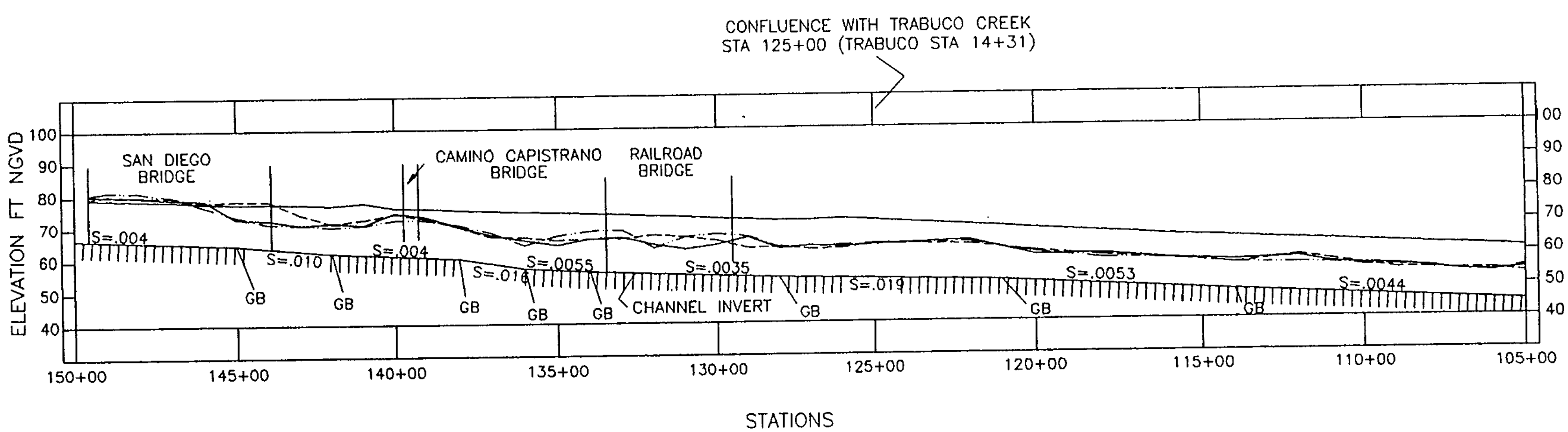
BOTTOM VELOCITIES
TYPE 2 DESIGN, SAN JUAN CREEK
Qsj = 42,000 CFS
Qtr = 17,000 CFS

NOTE: VELOCITIES MEASURED 1 FT FROM BOTTOM.
TO CONVERT DIMENSIONS GIVEN IN FEET TO METERS, MULTIPLY BY 0.3048.
TO CONVERT DIMENSIONS GIVEN IN CFS TO CU M/S, MULTIPLY BY 0.0283.

NOTE: VELOCITIES MEASURED 1 FT FROM BOTTOM.
TO CONVERT DIMENSIONS GIVEN IN FEET TO METERS, MULTIPLY BY 0.3048.
TO CONVERT DIMENSIONS GIVEN IN CFS TO CU M/S, MULTIPLY. BY 0.0283.



BOTTOM VELOCITIES
TYPE 2 DESIGN, TRABUCO CREEK
Qsj = 42,000 CFS
Qtr = 17,000 CFS



LEGEND

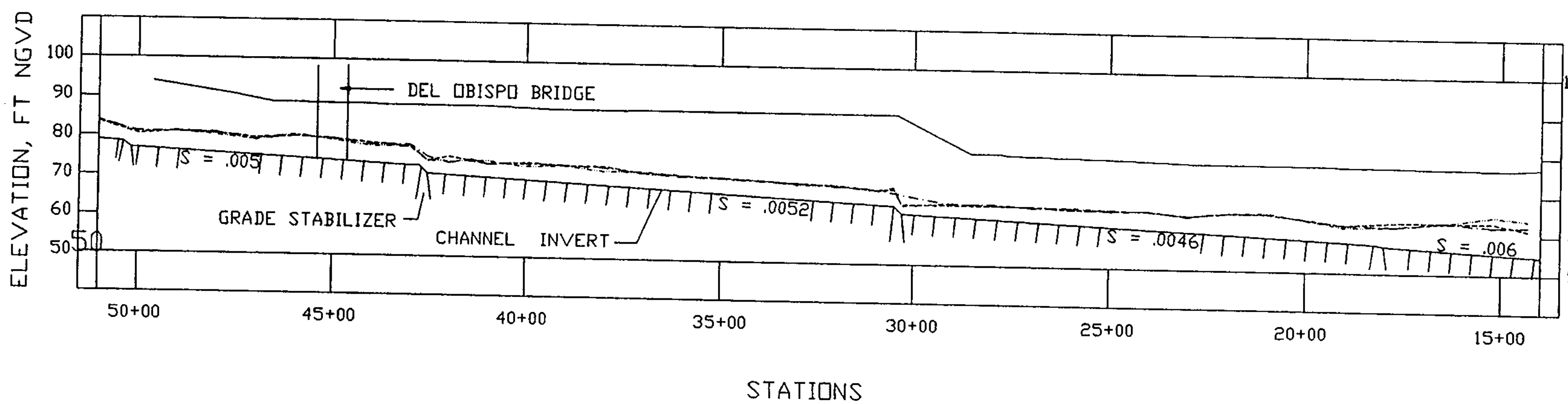
- CENTER LINE
- LEFT
- RIGHT
- TOP OF SLOPE

GB – GRADE BREAK

NOTE: TO CONVERT DIMENSIONS GIVEN IN FEET TO METERS, MULTIPLY BY 0.3048.
TO CONVERT DIMENSIONS GIVEN IN CFS TO CU M/S, MULTIPLY BY 0.0283.

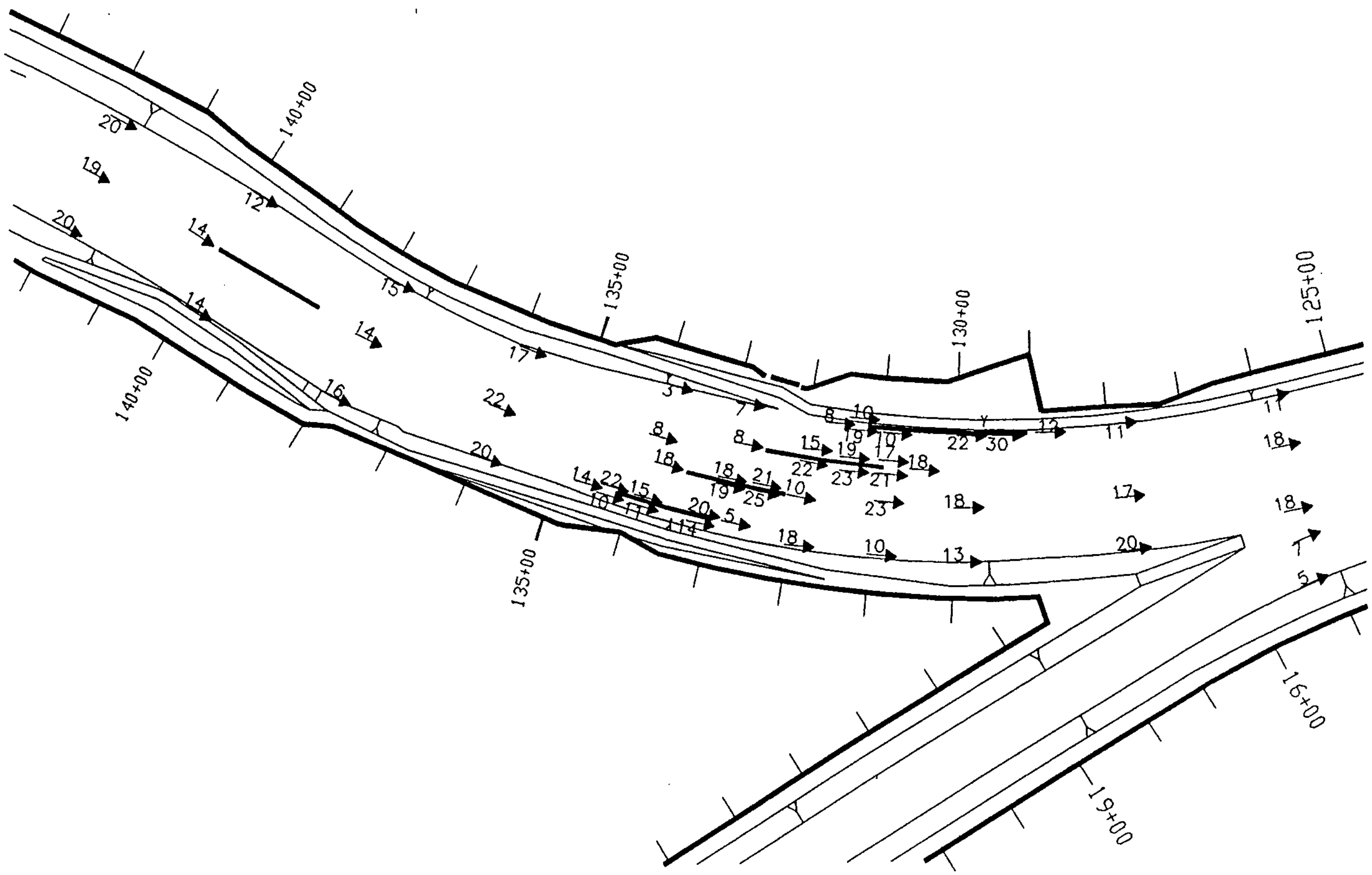
WATER-SURFACE PROFILES
TYPE 2 DESIGN, SAN JUAN CREEK

Qsj = 35,000 CFS
Qtr = 5,000 CFS



NOTE: TO CONVERT DIMENSIONS GIVEN IN FEET TO METERS, MULTIPLY BY 0.3048.
TO CONVERT DIMENSIONS GIVEN IN CFS TO CU M/S, MULTIPLY BY 0.0283.

WATER-SURFACE PROFILES
TYPE 2 DESIGN, TRABUCO CREEK
Qsj = 35,000 CFS
Qtr = 5,000 CFS



BOTTOM VELOCITIES

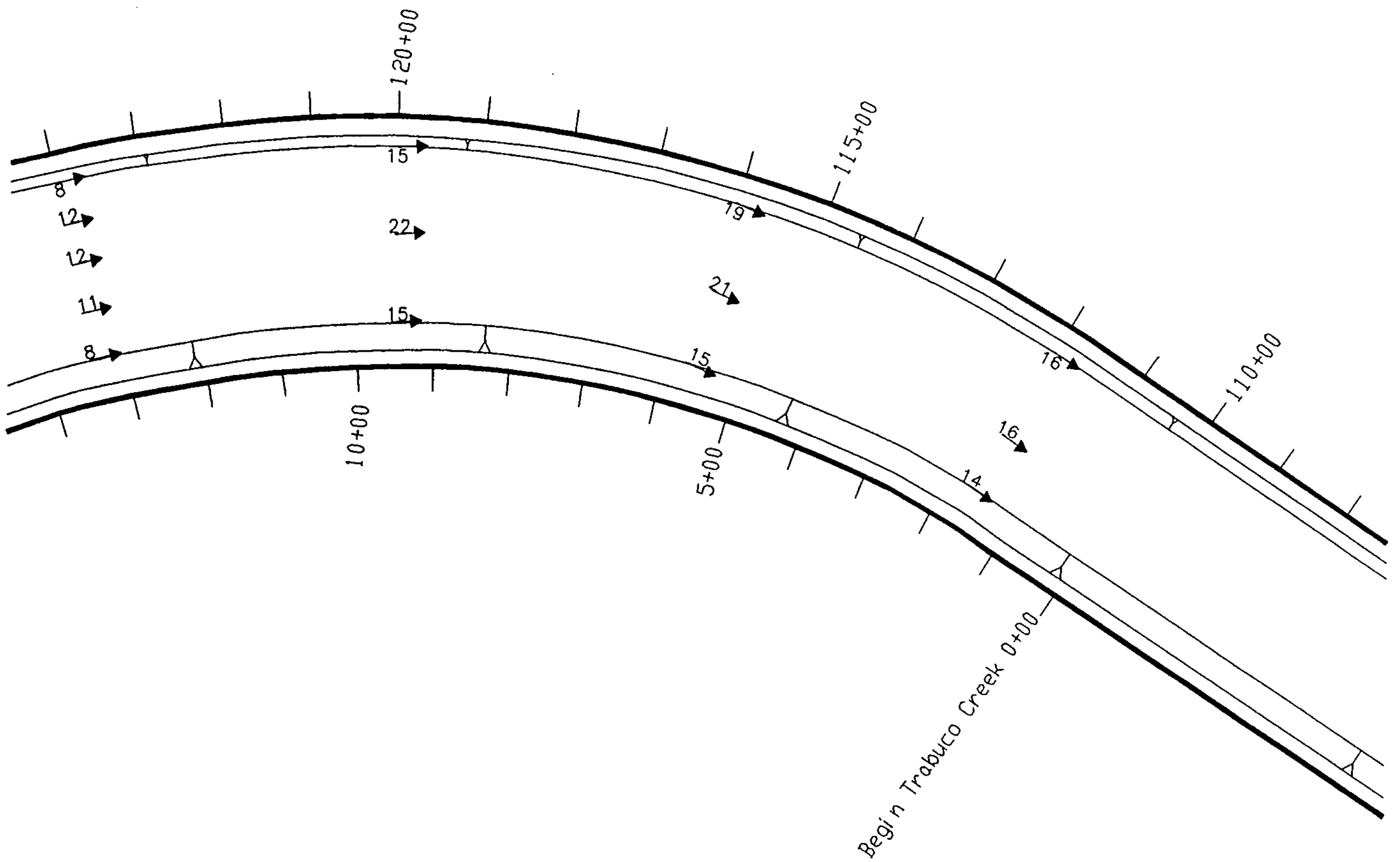
TYPE 2 DESIGN, CONFLUENCE OF SAN JUAN AND TRABUCO CREEKS

Qsj = 35,000 CFS

Qtr = 5,000 CFS

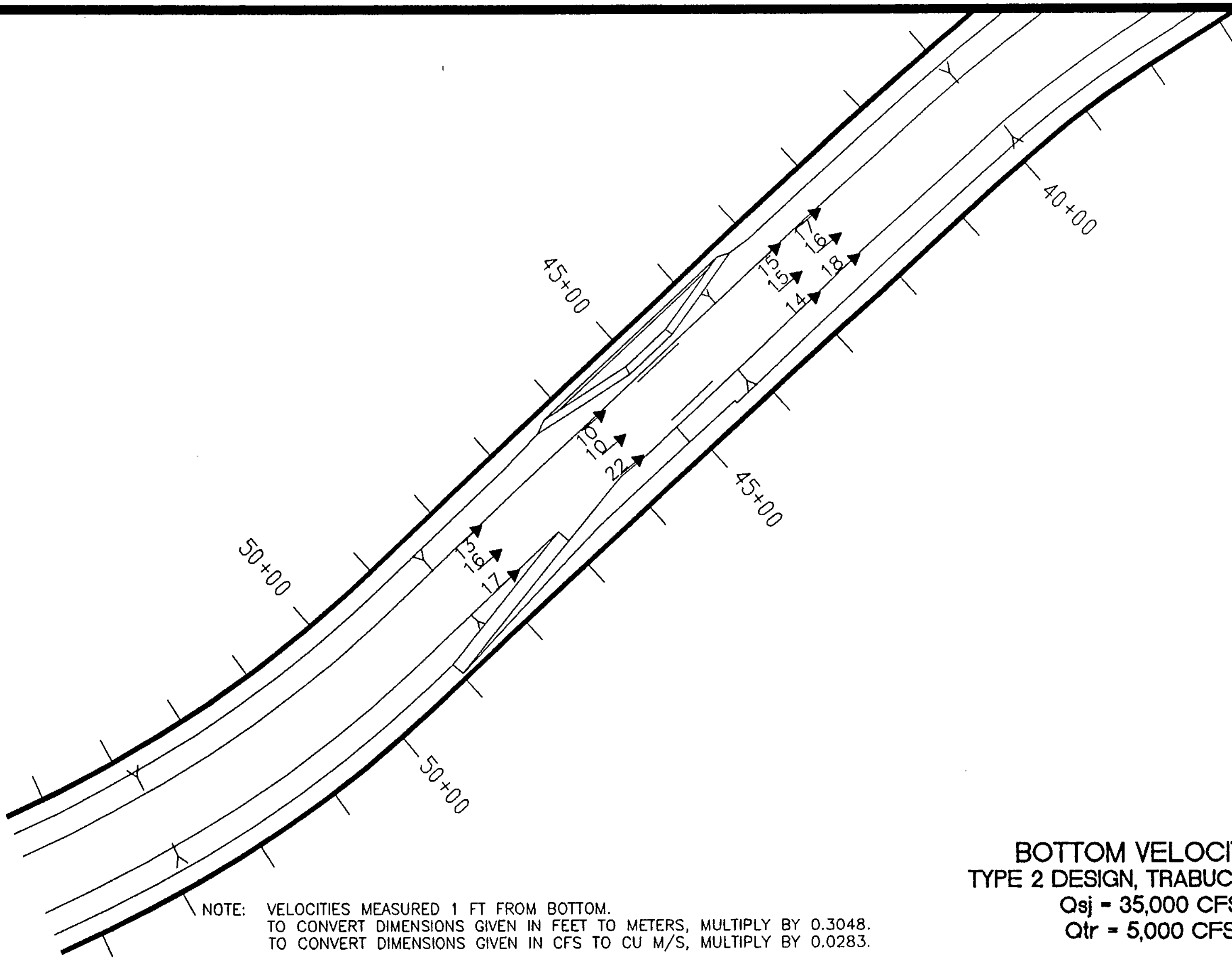
NOTE: VELOCITIES MEASURED 1 FT FROM BOTTOM.
TO CONVERT DIMENSIONS GIVEN IN FEET TO METERS, MULTIPLY BY 0.3048.
TO CONVERT DIMENSIONS GIVEN IN CFS TO CU M/S, MULTIPLY BY 0.0283.

Plate 26



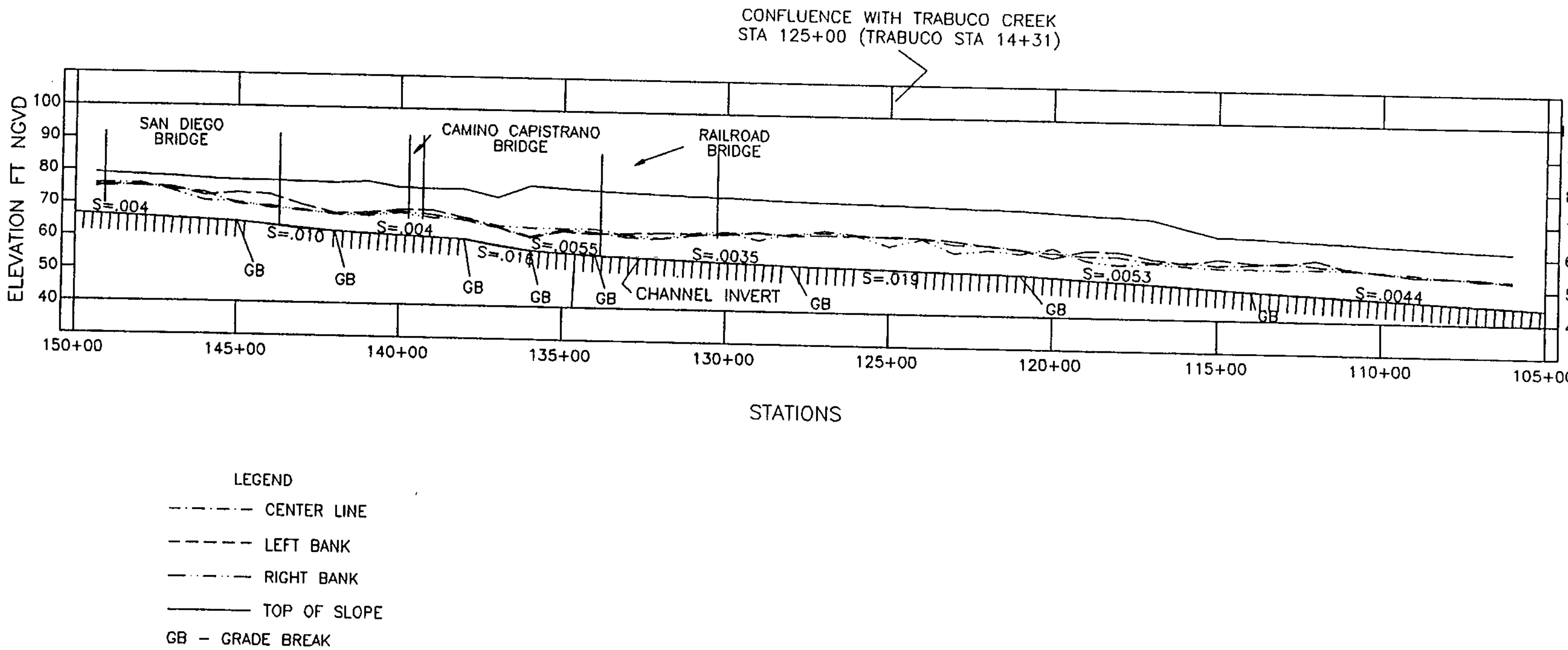
BOTTOM VELOCITIES
TYPE 2 DESIGN, SAN JUAN CREEK
Qsj = 35,000 CFS
Qtr = 5,000 CFS

NOTE: VELOCITIES MEASURED 1 FT FROM BOTTOM.
TO CONVERT DIMENSIONS GIVEN IN FEET TO METERS, MULTIPLY BY 0.3048.
TO CONVERT DIMENSIONS GIVEN IN CFS TO CU M/S, MULTIPLY BY 0.0283.



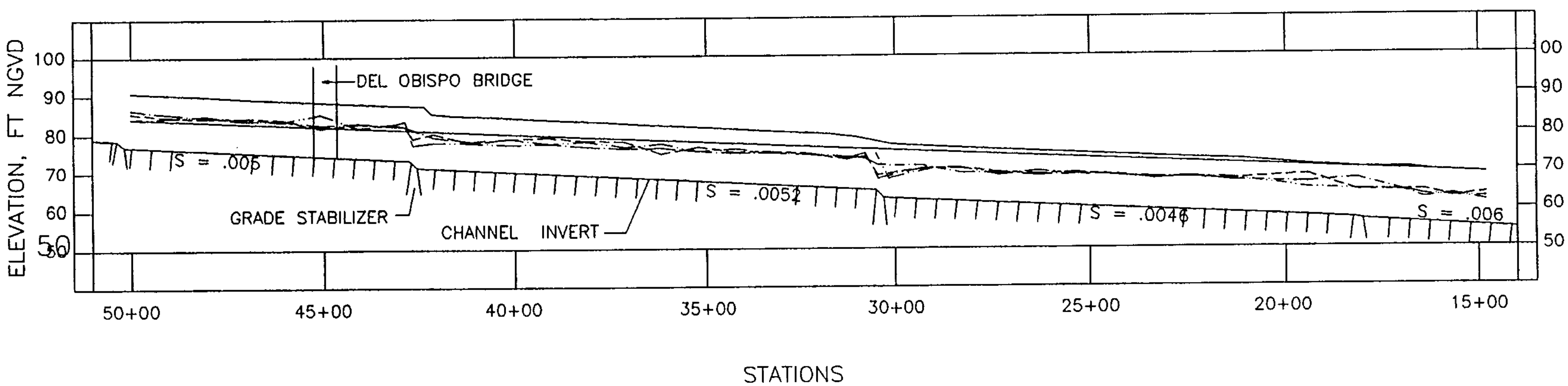
BOTTOM VELOCITIES
TYPE 2 DESIGN, TRABUCO CREEK
Qsj = 35,000 CFS
Qtr = 5,000 CFS

NOTE: VELOCITIES MEASURED 1 FT FROM BOTTOM.
TO CONVERT DIMENSIONS GIVEN IN FEET TO METERS, MULTIPLY BY 0.3048.
TO CONVERT DIMENSIONS GIVEN IN CFS TO CU M/S, MULTIPLY BY 0.0283.



NOTE: TO CONVERT DIMENSIONS GIVEN IN FEET TO METERS, MULTIPLY BY 0.3048.
TO CONVERT DIMENSIONS GIVEN IN CFS TO CU M/S, MULTIPLY BY 0.0283.

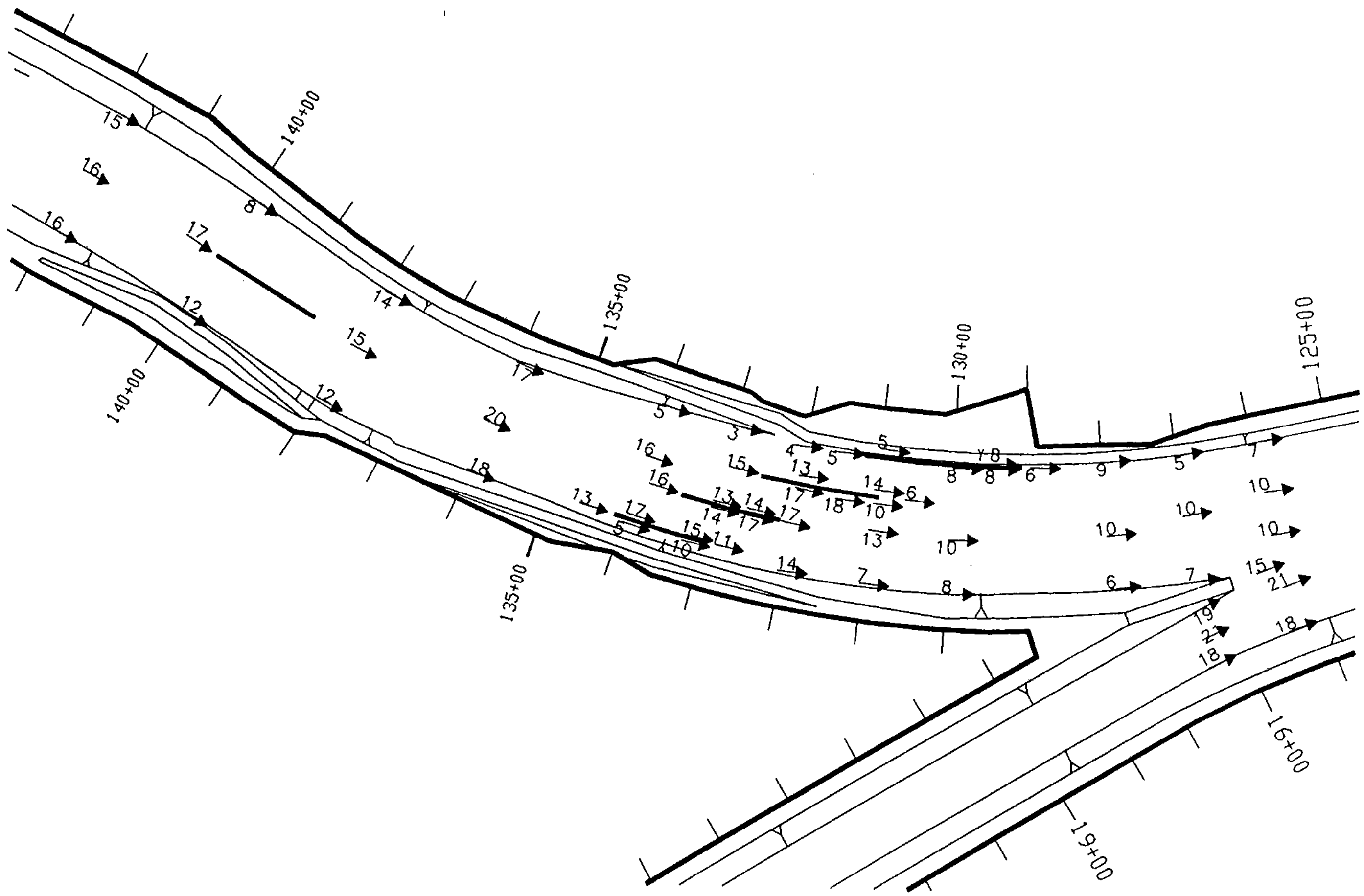
WATER-SURFACE PROFILES
TYPE 2 DESIGN, SAN JUAN CREEK
Qsj = 17,000 CFS
Qtr = 17,000 CFS



LEGEND
- CENTER LINE
- LEFT BANK
- RIGHT BANK
- TOP OF SLOPE

NOTE: TO CONVERT DIMENSIONS GIVEN IN FEET TO METERS, MULTIPLY BY 0.3048.
TO CONVERT DIMENSIONS GIVEN IN CFS TO CU M/S, MULTIPLY BY 0.0283.

WATER-SURFACE PROFILES
TYPE 2, DESIGNTRABUCO CREEK
Qsj = 17,000 CFS
Qtr = 17,000 CFS



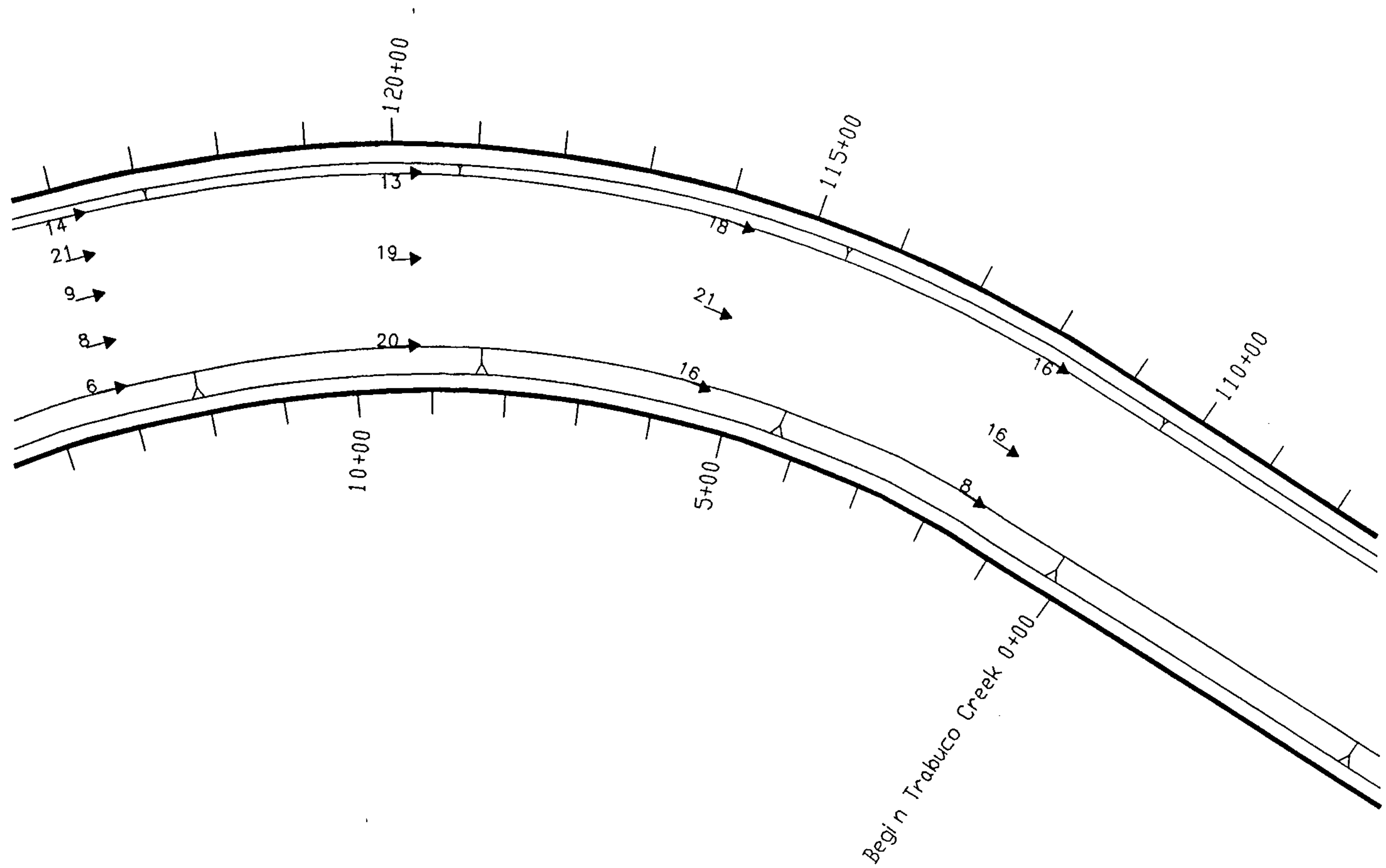
BOTTOM VELOCITIES

TYPE 2 DESIGN, CONFLUENCE OF SAN JUAN AND TRABUCO CREEK

Qsj - 17,000 CFS

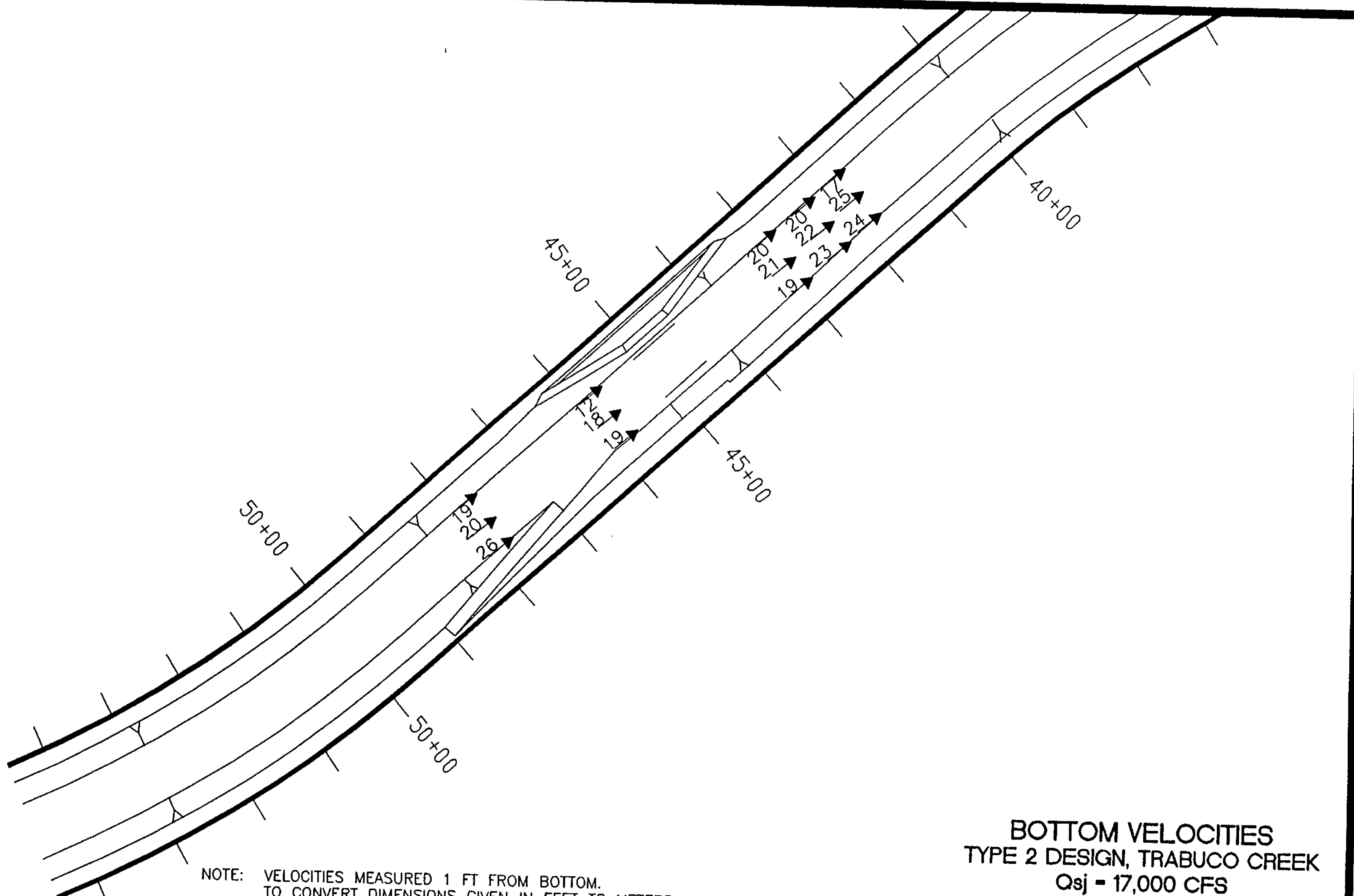
Qtr - 17,000 CFS

NOTE: VELOCITIES MEASURED 1 FT FROM BOTTOM.
TO CONVERT DIMENSIONS GIVEN IN FEET TO METERS, MULTIPLY BY 0.3048.
TO CONVERT DIMENSIONS GIVEN IN CFS TO CU M/S, MULTIPLY BY 0.0283.



BOTTOM VELOCITIES
TYPE 2 DESIGN, SAN JUAN CREEK
Qsj = 17,000 CFS
Qtr = 17,000 CFS

NOTE: VELOCITIES MEASURED 1 FT FROM BOTTOM.
TO CONVERT DIMENSIONS GIVEN IN FEET TO METERS, MULTIPLY BY 0.3048.
TO CONVERT DIMENSIONS GIVEN IN CFS TO CU M/S, MULTIPLY BY 0.0283.



NOTE: VELOCITIES MEASURED 1 FT FROM BOTTOM.
TO CONVERT DIMENSIONS GIVEN IN FEET TO METERS, MULTIPLY BY 0.3048.
TO CONVERT DIMENSIONS GIVEN IN CFS TO CU M/S, MULTIPLY BY 0.0283.

BOTTOM VELOCITIES
TYPE 2 DESIGN, TRABUCO CREEK
Qsj - 17,000 CFS
Qtr - 17,000 CFS

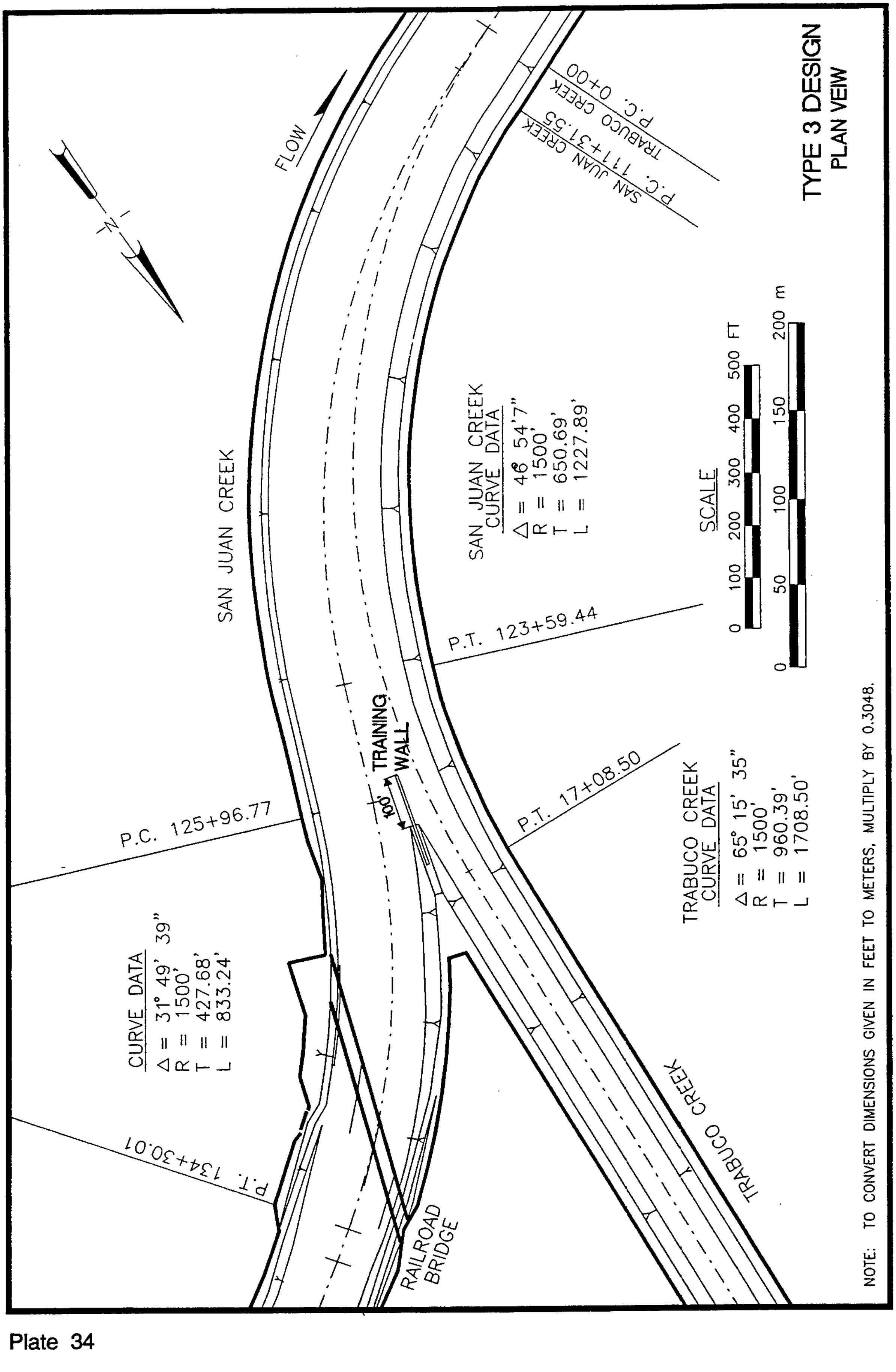
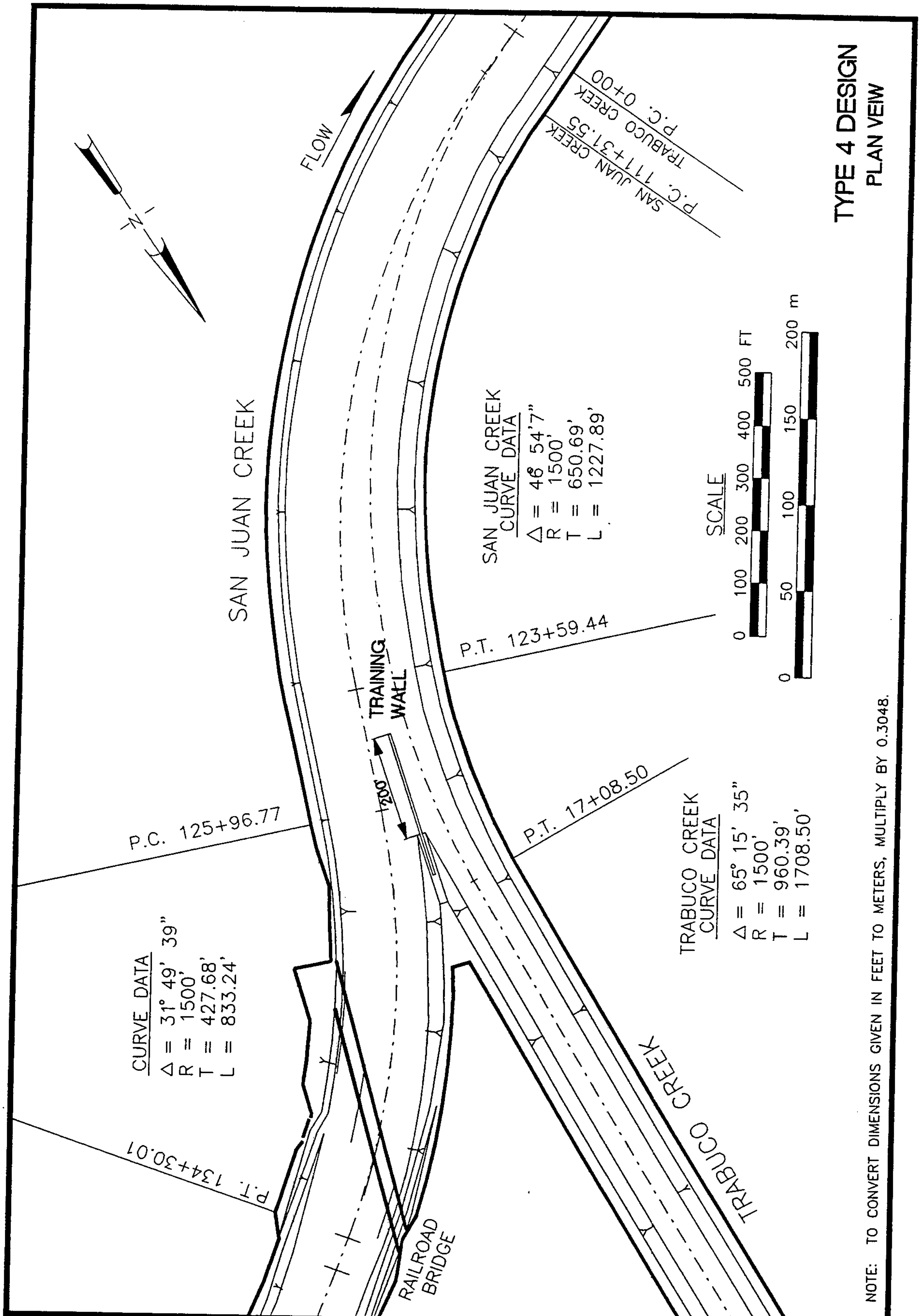
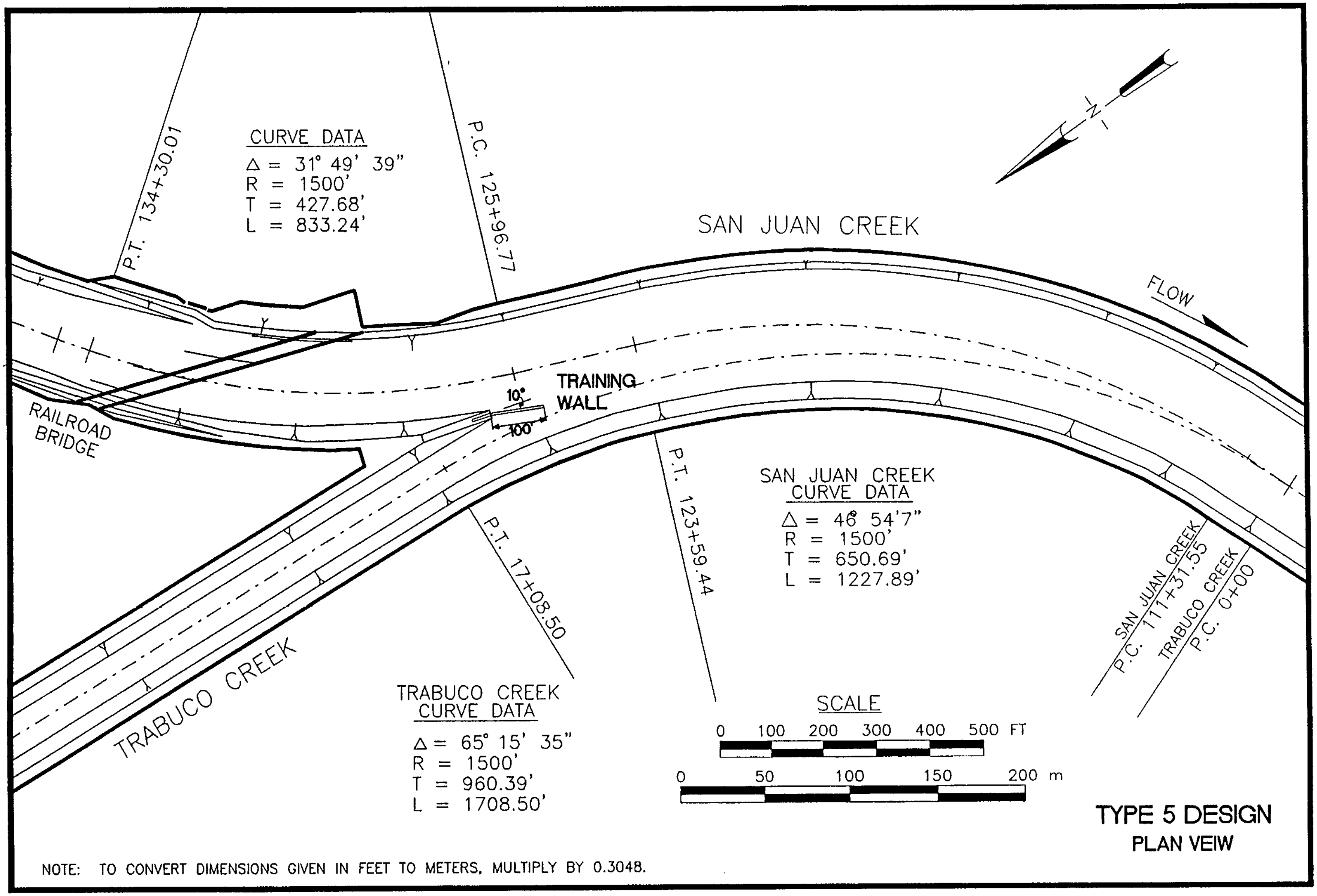

TYPE 3 DESIGN
PLAN VEIW
FLOW
N
SAN JUAN CREEK
TRABUCO CREEK
P.C. 0+00
TRABUCO CREEK
P.C. 111+31.55
SAN JUAN CREEK
P.T. 123+59.44
P.C. 125+96.77
P.T. 17+08.50
P.T. 134+30.01
TRAINING WALL
100'
RAILROAD BRIDGE
CURVE DATA
Δ = 31° 49' 39"
R = 1500'
T = 427.68'
L = 833.24'
SAN JUAN CREEK CURVE DATA
Δ = 46° 54' 7"
R = 1500'
T = 650.69'
L = 1227.89'
TRABUCO CREEK CURVE DATA
Δ = 65° 15' 35"
R = 1500'
T = 960.39'
L = 1708.50'
SCALE
0 100 200 300 400 500 FT
0 50 100 150 200 m
NOTE: TO CONVERT DIMENSIONS GIVEN IN FEET TO METERS, MULTIPLY BY 0.3048.

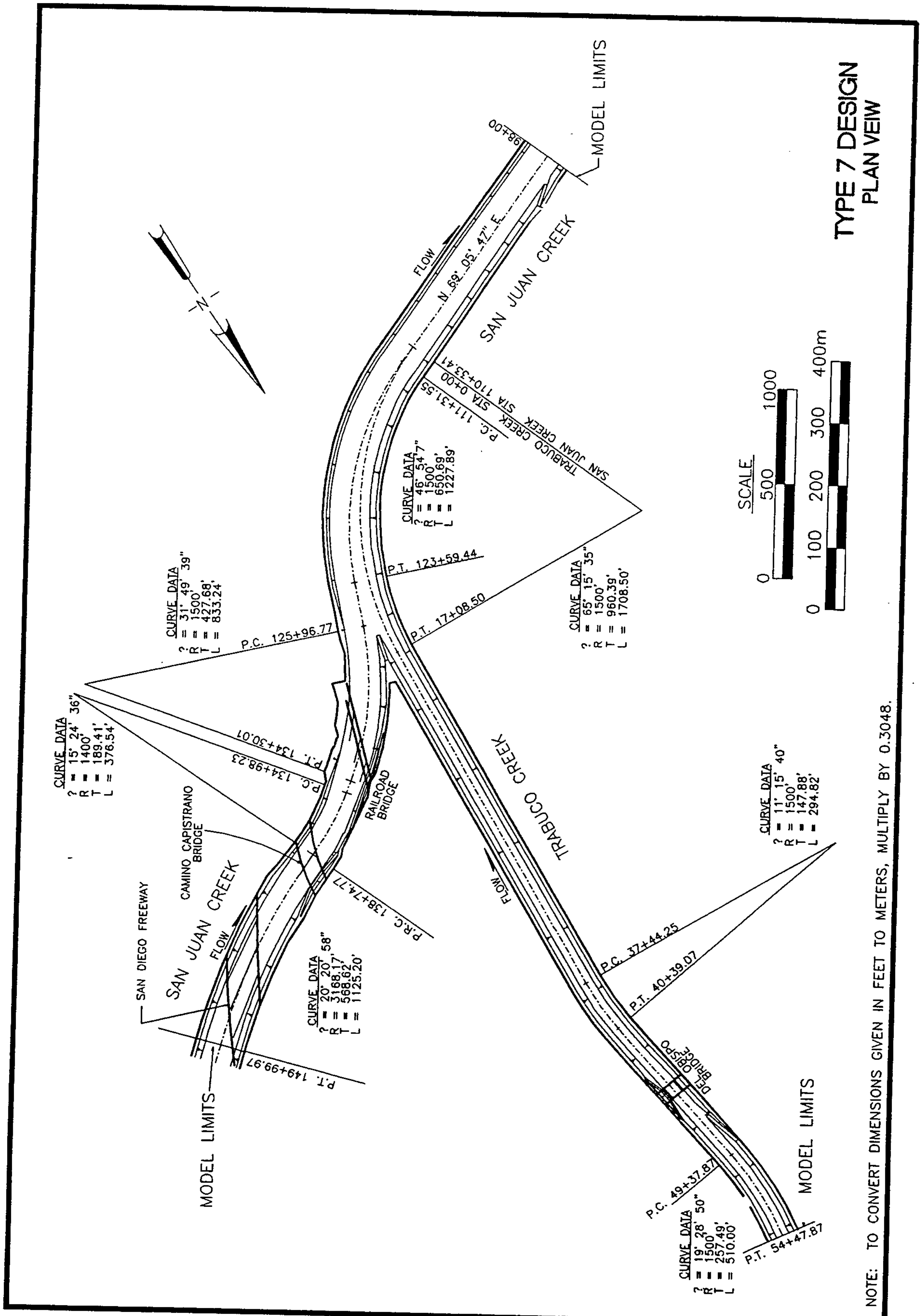
Plate 34


TYPE 4 DESIGN
PLAN VEIW
SAN JUAN CREEK
FLOW
N
P.C. 0+00
TRABUCO CREEK
P.C. 111+31.55
SAN JUAN CREEK
SAN JUAN CREEK
CURVE DATA
Δ = 46° 54'7"
R = 1500'
T = 650.69'
L = 1227.89'
SCALE
0 100 200 300 400 500 FT
0 50 100 150 200 m
P.T. 123+59.44
TRAINING
WALL
200'
P.C. 125+96.77
P.T. 17+08.50
TRABUCO CREEK
CURVE DATA
Δ = 65° 15' 35"
R = 1500'
T = 960.39'
L = 1708.50'
CURVE DATA
Δ = 31° 49' 39"
R = 1500'
T = 427.68'
L = 833.24'
P.T. 134+30.01
RAILROAD
BRIDGE
TRABUCO CREEK
NOTE: TO CONVERT DIMENSIONS GIVEN IN FEET TO METERS, MULTIPLY BY 0.3048.

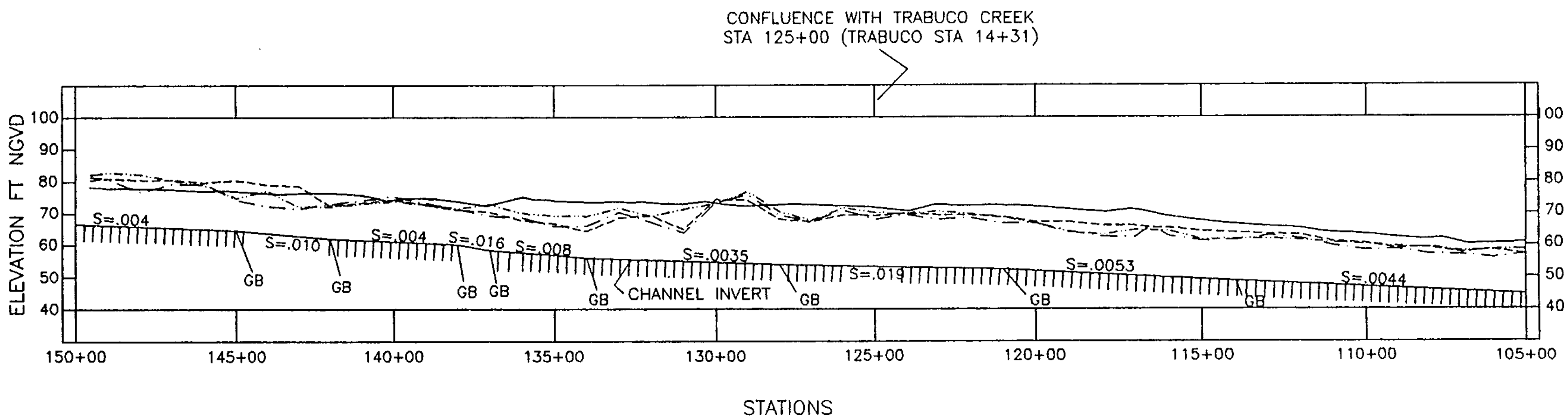


TYPE 5 DESIGN
PLAN VEIW

NOTE: TO CONVERT DIMENSIONS GIVEN IN FEET TO METERS, MULTIPLY BY 0.3048.



TYPE 7 DESIGN
PLAN VEIW
SAN JUAN CREEK
TRABUCO CREEK
SAN DIEGO FREEWAY
CAMINO CAPISTRANO BRIDGE
RAILROAD BRIDGE
DEL OBISPO BRIDGE
MODEL LIMITS
MODEL LIMITS
MODEL LIMITS
FLOW
FLOW
FLOW
N
N 69° 05' 47" E
198+00
SAN JUAN CREEK STA 110+33.41
TRABUCO CREEK STA 0+00
P.C. 111+31.55
P.T. 123+59.44
P.C. 125+96.77
P.T. 17+08.50
P.T. 134+30.01
P.C. 134+98.23
P.R.C. 138+74.77
P.T. 149+99.97
P.C. 37+44.25
P.T. 40+39.07
P.C. 49+37.87
P.T. 54+47.87
CURVE DATA
? = 46° 54' 7"
R = 1500'
T = 650.69'
L = 1227.89'
CURVE DATA
? = 31° 49' 39"
R = 1500'
T = 427.68'
L = 833.24'
CURVE DATA
? = 65° 15' 35"
R = 1500'
T = 960.39'
L = 1708.50'
CURVE DATA
? = 15° 24' 36"
R = 1400'
T = 189.41'
L = 376.54'
CURVE DATA
? = 11° 15' 40"
R = 1500'
T = 147.88'
L = 294.82'
CURVE DATA
? = 20° 20' 58"
R = 3168.17'
T = 568.62'
L = 1125.20'
CURVE DATA
? = 19° 28' 50"
R = 1500'
T = 257.49'
L = 510.00'
SCALE
0 500 1000
0 100 200 300 400m
NOTE: TO CONVERT DIMENSIONS GIVEN IN FEET TO METERS, MULTIPLY BY 0.3048.



LEGEND

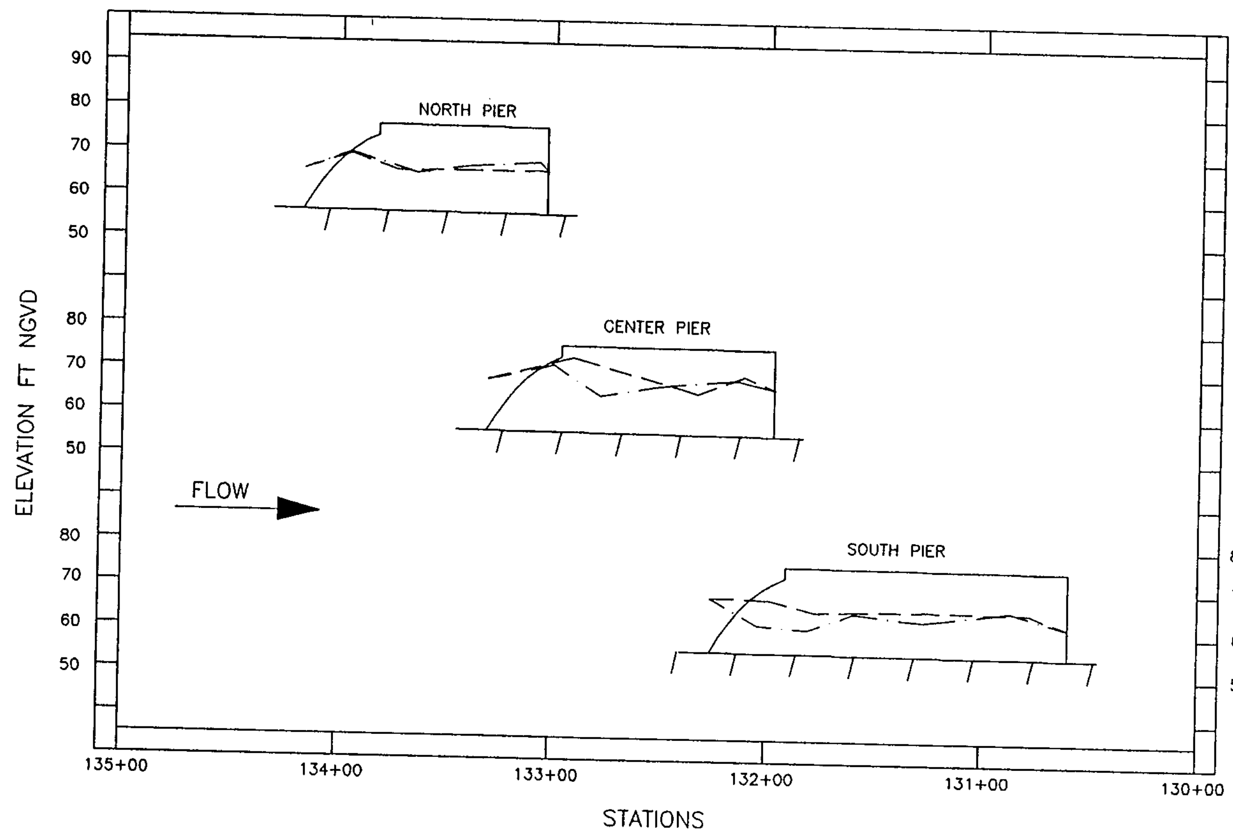
- CENTER LINE
- LEFT BANK
- RIGHT BANK
- TOP OF SLOPE

GB – GRADE BREAK

NOTE: TO CONVERT DIMENSIONS GIVEN IN FEET TO METERS, MULTIPLY BY 0.3048.
TO CONVERT DIMENSIONS GIVEN IN CFS TO CU M/S, MULTIPLY BY 0.0283.

WATER-SURFACE PROFILES
TYPE 7 DESIGN, SAN JUAN CREEK
Qsj = 42,000 CFS
Qtr = 17,000 CFS

Plate 38



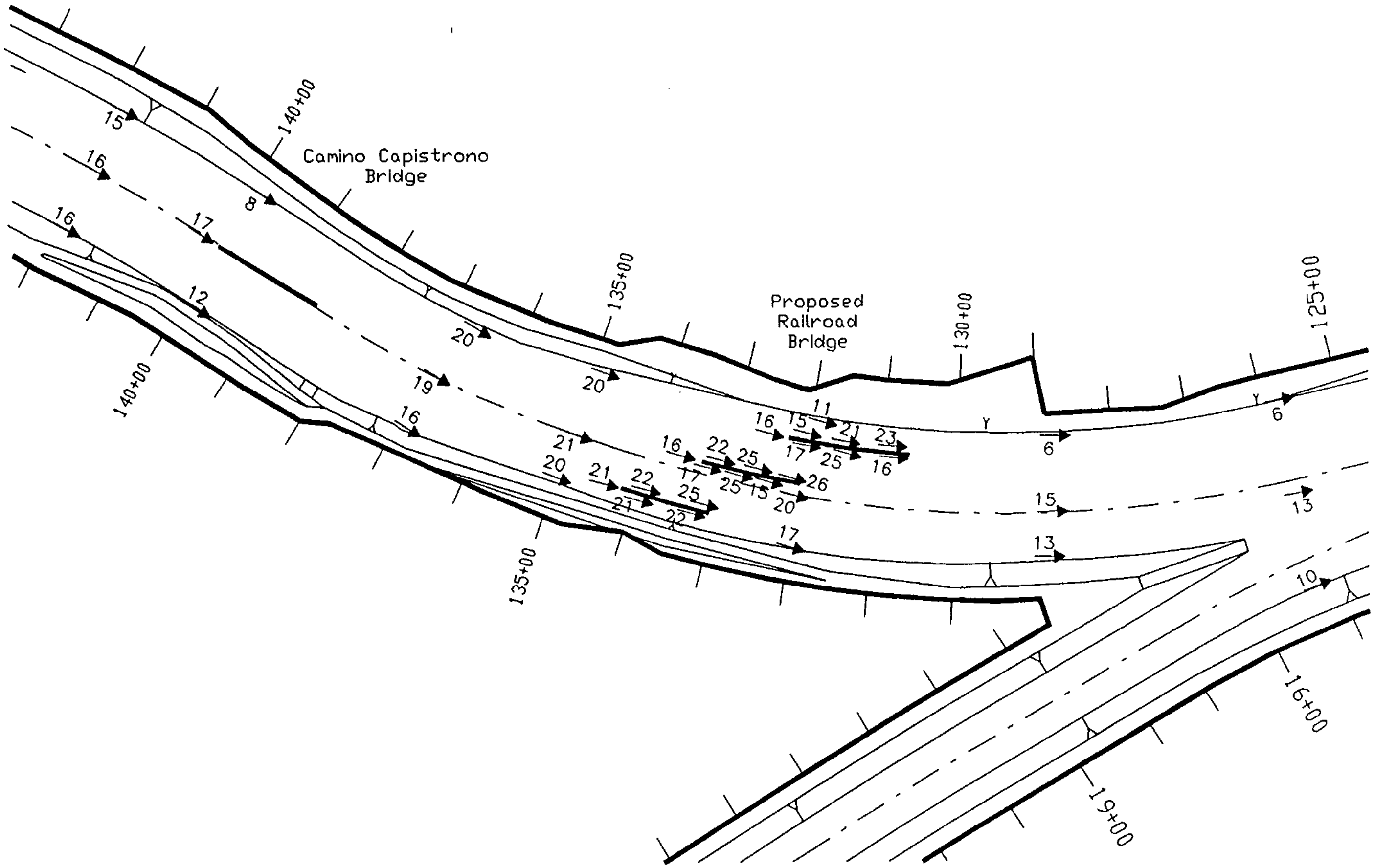
LEGEND

— — · — RIGHT SIDE OF PIER

— — — — LEFT SIDE OF PIER

NOTE: TO CONVERT DIMENSIONS GIVEN IN FEET TO METERS, MULTIPLY BY 0.3048.
TO CONVERT DIMENSIONS GIVEN IN CFS TO CU M/S, MULTIPLY BY 0.0283.

WATER-SURFACE PROFILES
TYPE 7 DESIGN, SAN JUAN CREEK
PROPOSED RAILROAD BRIDGE
Qsj = 42,000 CFS
Qtr = 17,000 CFS



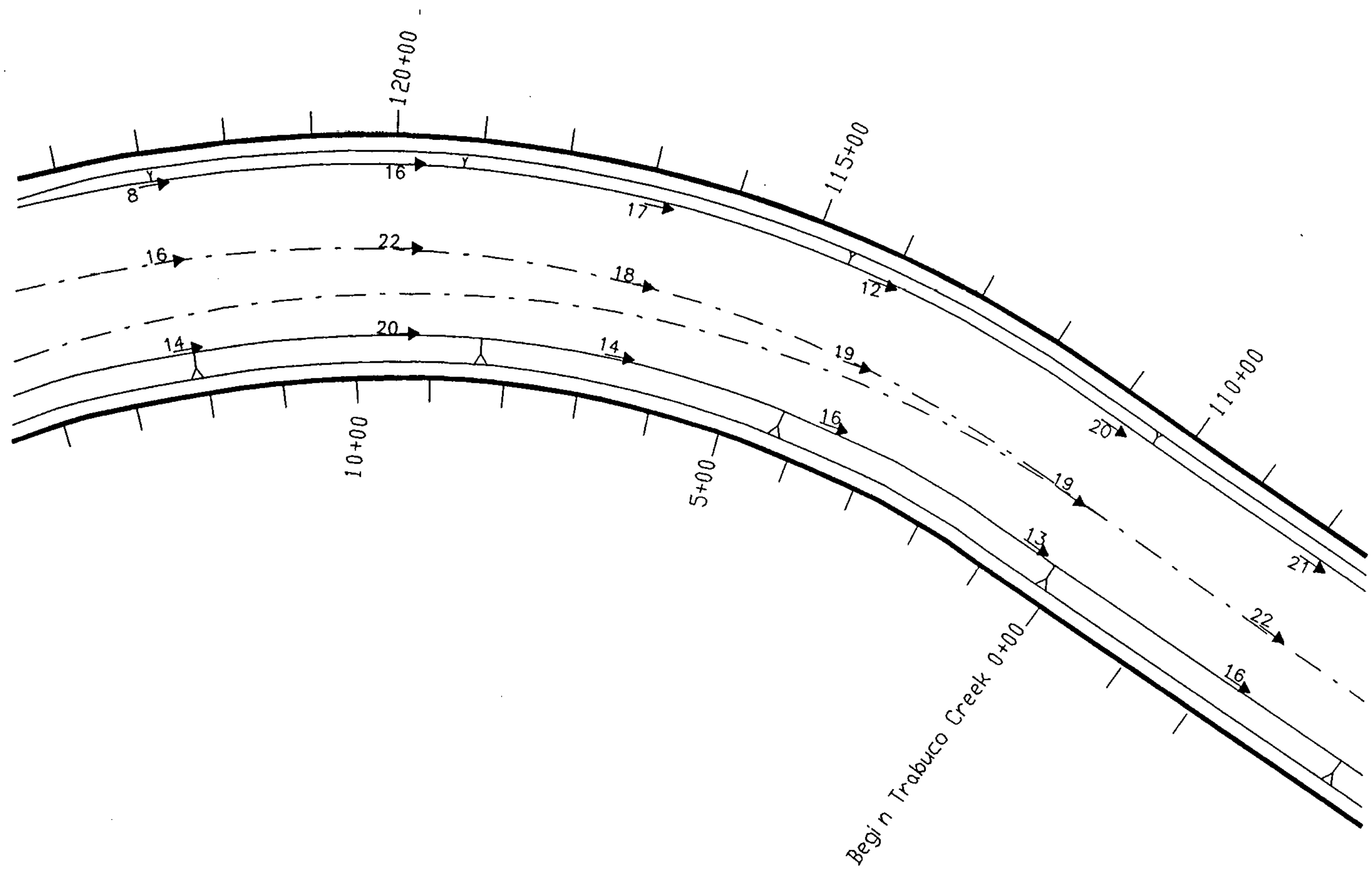
NOTE: VELOCITIES MEASURED 1 FT FROM BOTTOM.
TO CONVERT DIMENSIONS GIVEN IN FEET TO METERS, MULTIPLY BY 0.3048.
TO CONVERT DIMENSIONS GIVEN IN CFS TO CU M/S, MULTIPLY BY 0.0283.

BOTTOM VELOCITIES

TYPE 7 DESIGN, CONFLUENCE OF SAN JUAN AND TRABUCO CREEKS

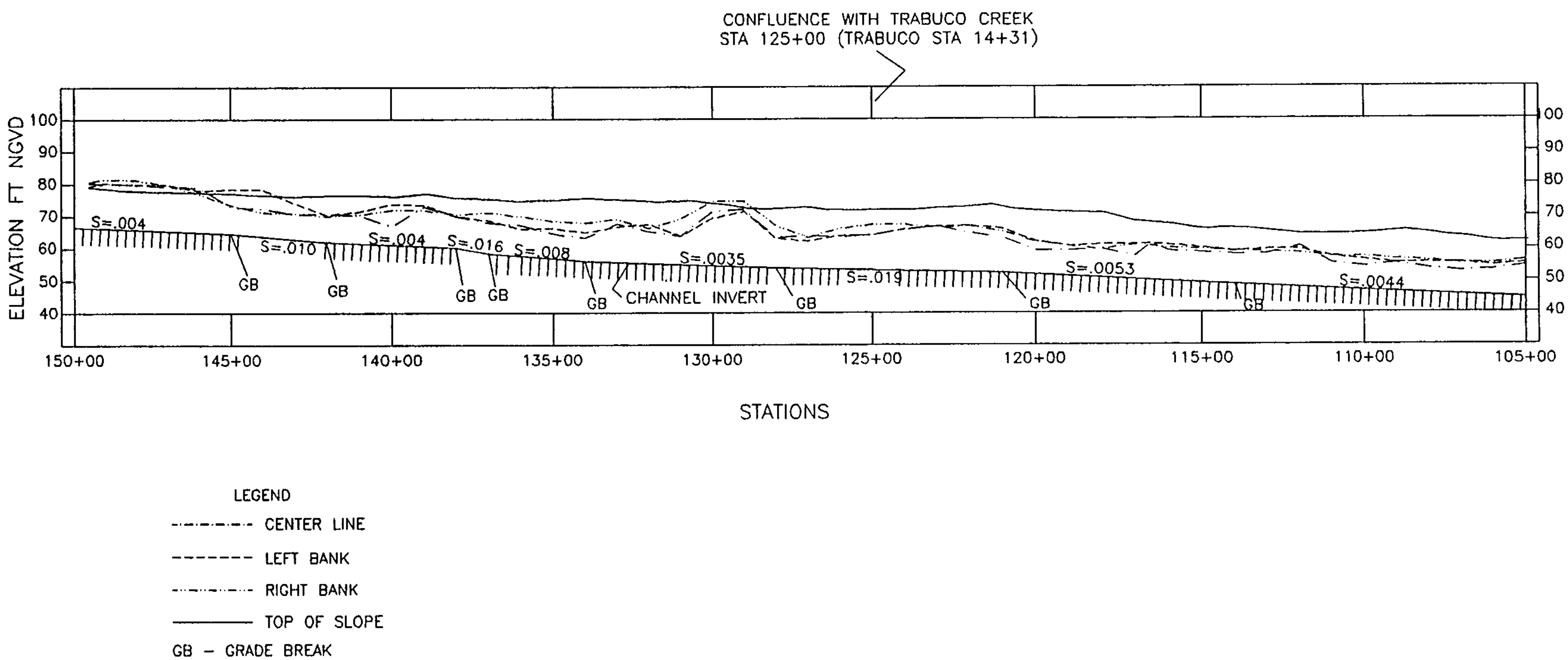
Qsj = 42,000 CFS

Qtr = 17,000 CFS



BOTTOM VELOCITIES
TYPE 7 DESIGN, SAN JUAN CREEK
Qsj - 42,000 CFS
Qtr - 17,000 CFS

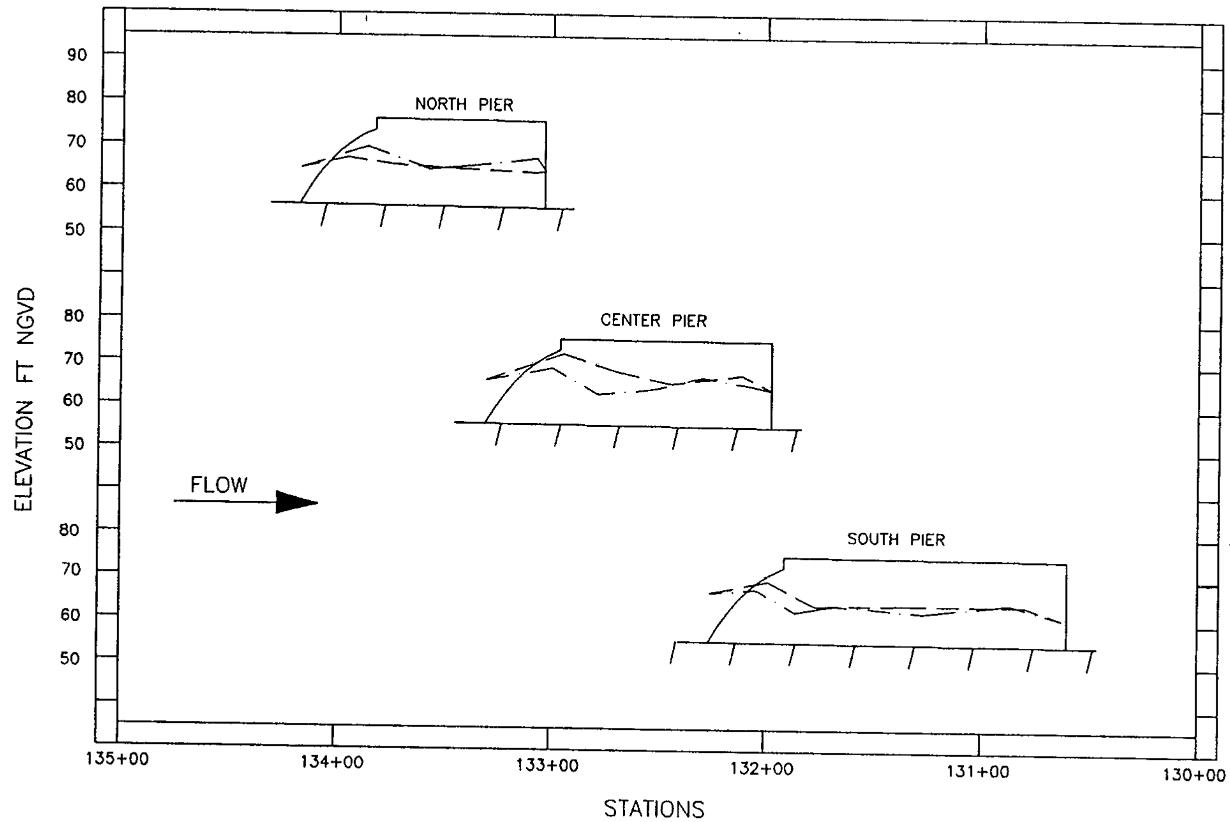
NOTE: VELOCITIES MEASURED 1 FT FROM BOTTOM.
TO CONVERT DIMENSIONS GIVEN IN FEET TO METERS, MULTIPLY BY 0.3048.
TO CONVERT DIMENSIONS GIVEN IN CFS TO CU M/S, MULTIPLY BY 0.0283.



WATER-SURFACE PROFILES
TYPE 7 DESIGN, SAN JUAN CREEK

Qsj = 35,000 CFS
Qtr = 5,000 CFS

NOTE: TO CONVERT DIMENSIONS GIVEN IN FEET TO METERS, MULTIPLY BY 0.3048.
TO CONVERT DIMENSIONS GIVEN IN CFS TO CU M/S, MULTIPLY BY 0.0283.

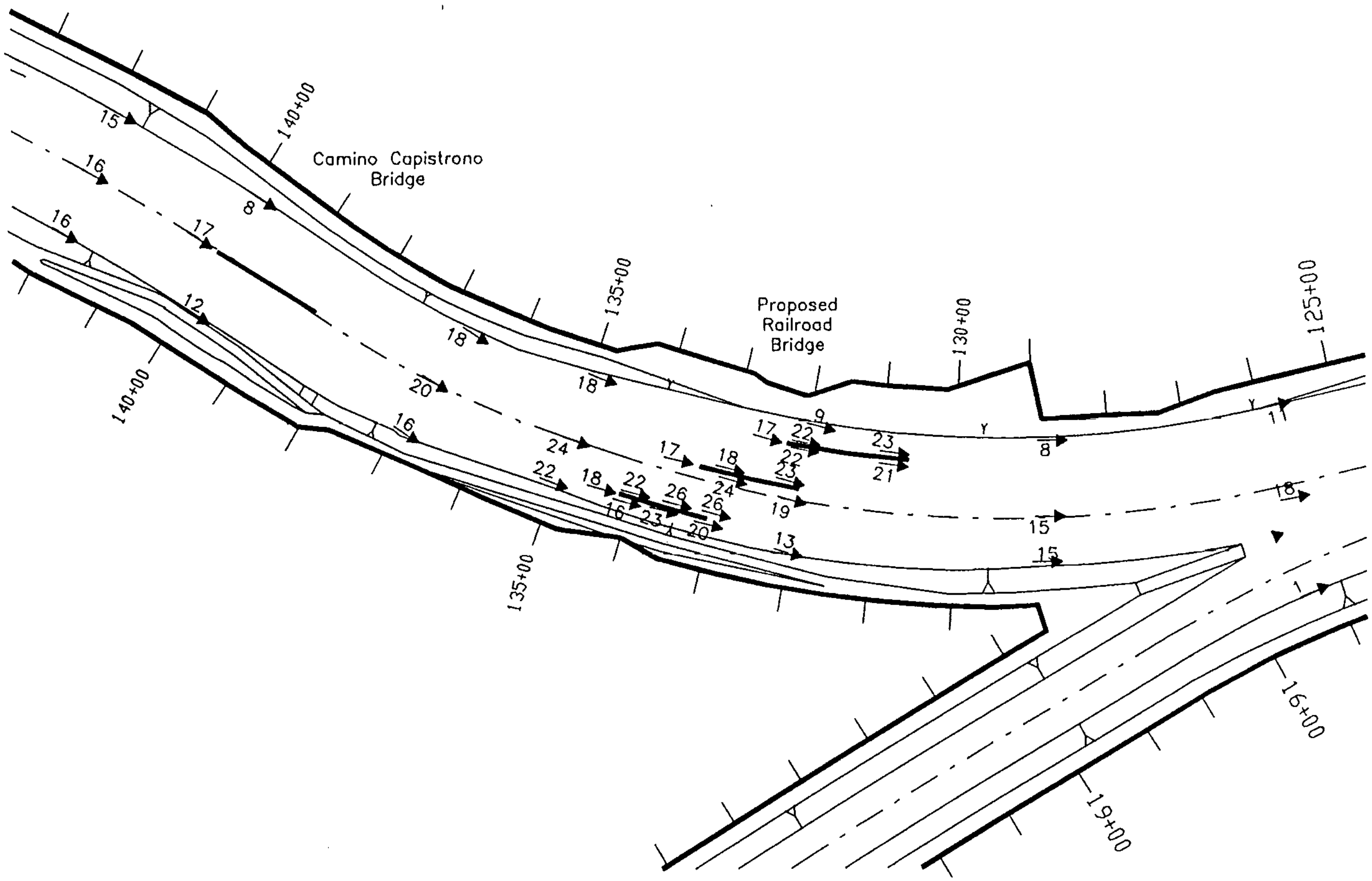


LEGEND

— · — · — RIGHT SIDE OF PIER
— — — — LEFT SIDE OF PIER

NOTE: TO CONVERT DIMENSIONS GIVEN IN FEET TO METERS, MULTIPLY BY 0.3048.
TO CONVERT DIMENSIONS GIVEN IN CFS TO CU M/S, MULTIPLY BY 0.0283.

WATER-SURFACE PROFILES
TYPE 7 DESIGN, SAN JUAN CREEK
PROPOSED RAILROAD BRIDGE
Qsj = 35,000 CFS
Qtr = 5,000 CFS



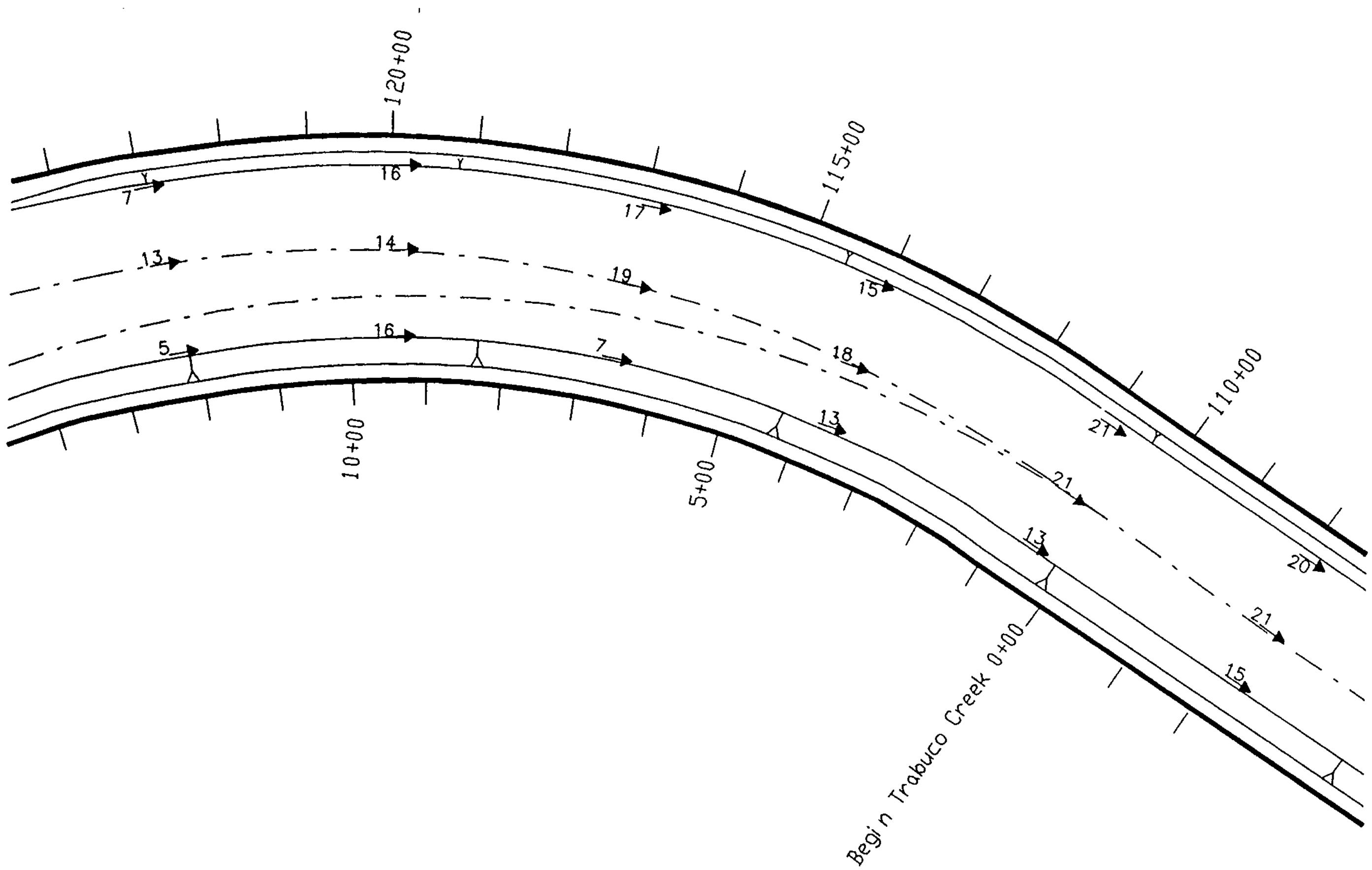
NOTE: VELOCITIES MEASURED 1 FT FROM BOTTOM.
TO CONVERT DIMENSIONS GIVEN IN FEET TO METERS, MULTIPLY BY 0.3048.
TO CONVERT DIMENSIONS GIVEN IN CFS TO CU M/S, MULTIPLY BY 0.0283.

BOTTOM VELOCITIES

TYPE 7 DESIGN, CONFLUENCE OF SAN JUAN AND TRABUCO CREEKS

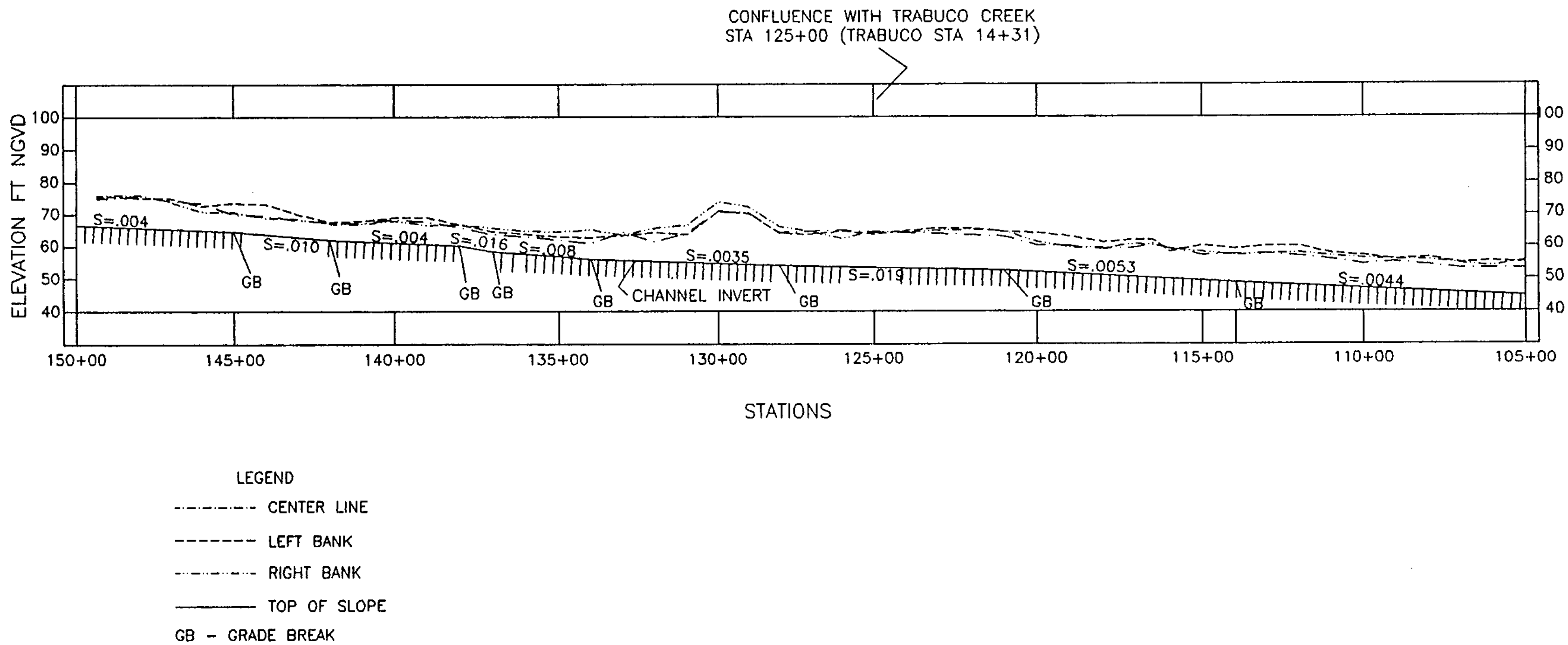
Qsj = 35,000 CFS

Qtr = 5,000 CFS



NOTE: VELOCITIES MEASURED 1 FT FROM BOTTOM.
TO CONVERT DIMENSIONS GIVEN IN FEET TO METERS, MULTIPLY BY 0.3048.
TO CONVERT DIMENSIONS GIVEN IN CFS TO CU M/S, MULTIPLY BY 0.0283.

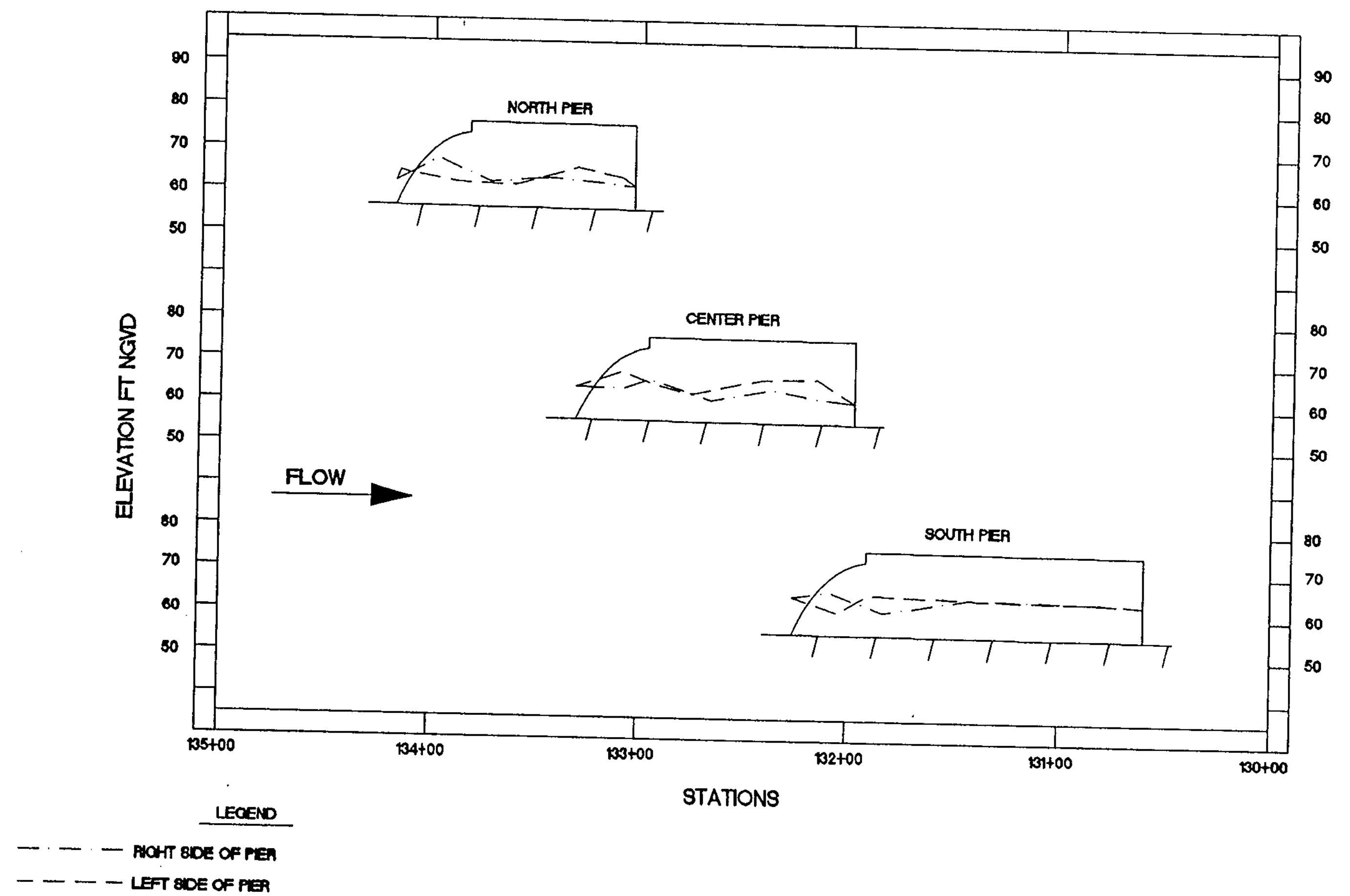
BOTTOM VELOCITIES
TYPE 7 DESIGN, SAN JUAN CREEK
Qsj = 35,000 CFS
Qtr = 5,000 CFS



WATER-SURFACE PROFILES
TYPE 7 DESIGN, SAN JUAN CREEK

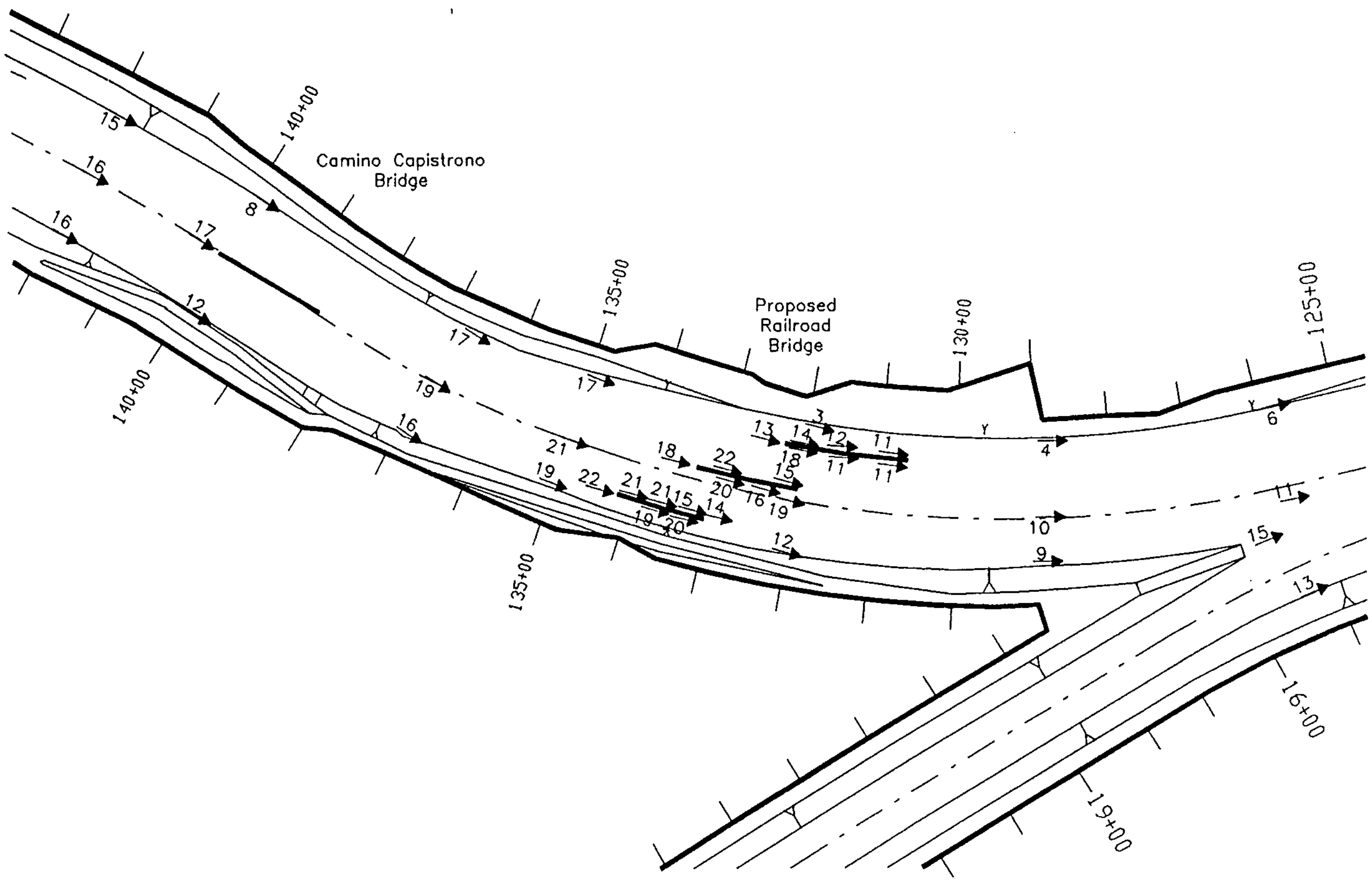
Qsj = 17,000 CFS
Qtr = 17,000 CFS

NOTE: TO CONVERT DIMENSIONS GIVEN IN FEET TO METERS, MULTIPLY BY 0.3048.
TO CONVERT DIMENSIONS GIVEN IN CFS TO CU M/S, MULTIPLY BY 0.0283.



NOTE: TO CONVERT DIMENSIONS GIVEN IN FEET TO METERS, MULTIPLY BY 0.3048.
TO CONVERT DIMENSIONS GIVEN IN CFS TO CU M/S, MULTIPLY BY 0.0283.

WATER-SURFACE PROFILES
TYPE 7 DESIGN, SAN JUAN CREEK
PROPOSED RAILROAD BRIDGE
Qsj = 17,000 CFS
Qtr = 17,000 CFS



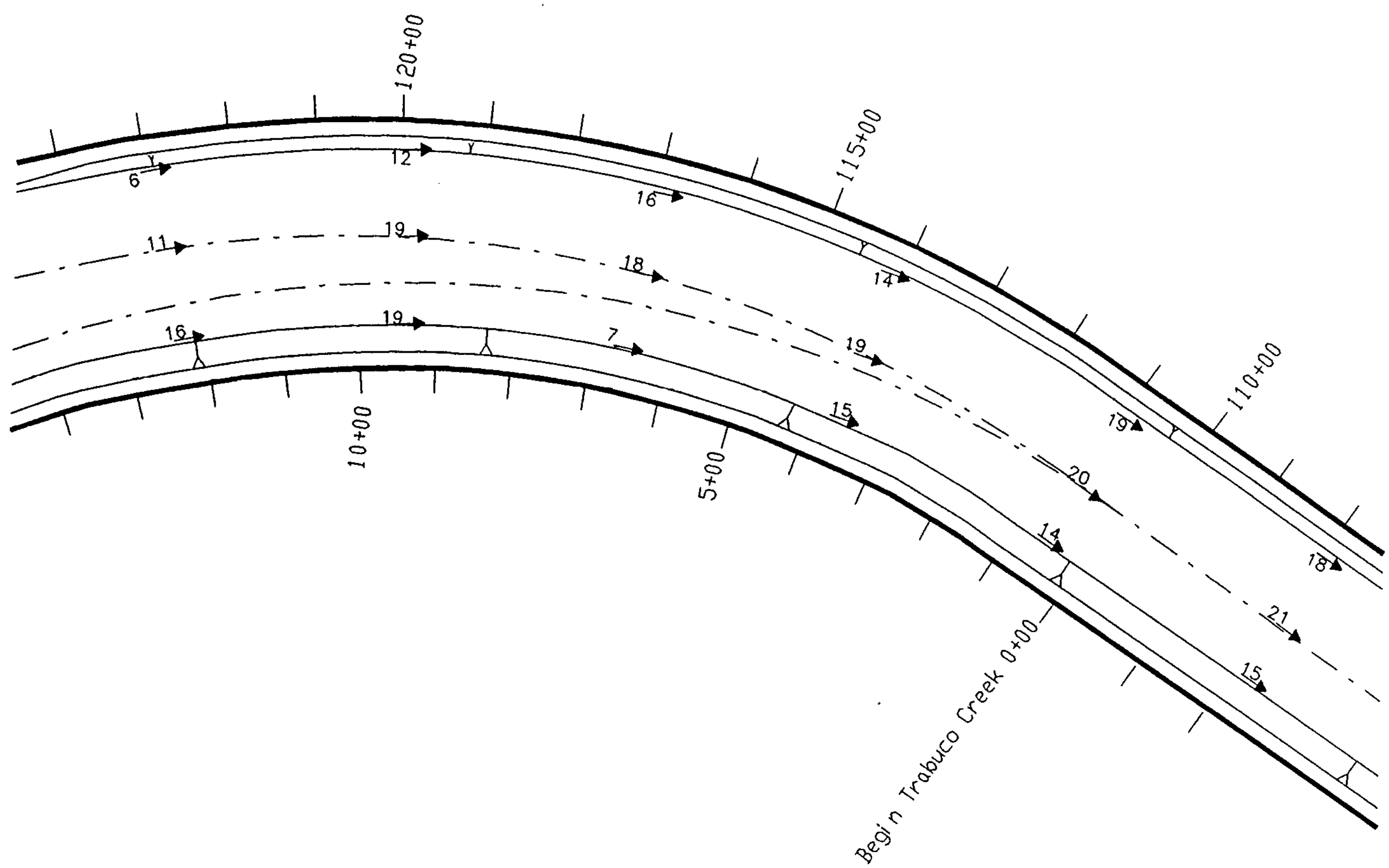
BOTTOM VELOCITIES

TYPE 7 DESIGN, CONFLUENCE OF SAN JUAN AND TRABUCO CREEKS

Qsj = 17,000 CFS

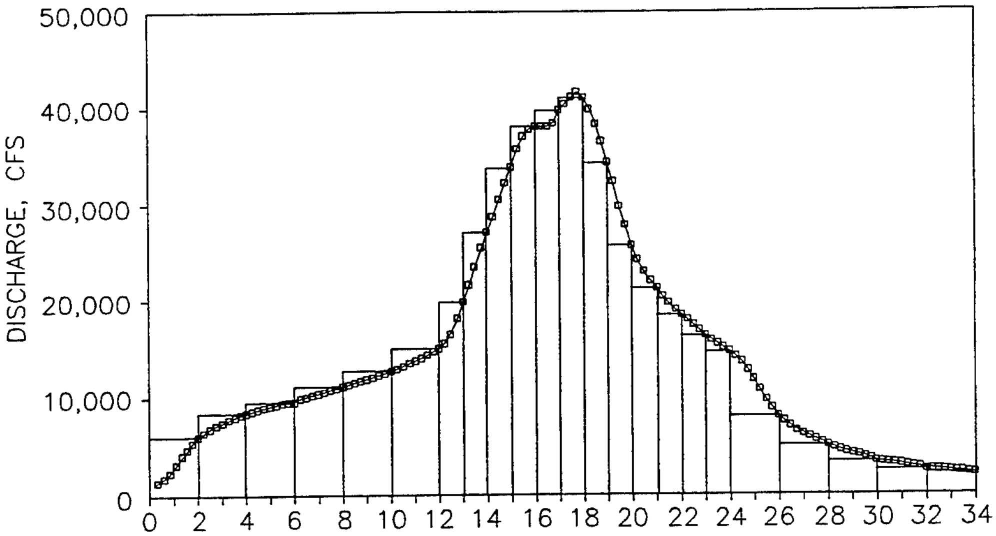
Qtr = 17,000 CFS

NOTE: VELOCITIES MEASURED 1 FT FROM BOTTOM.
TO CONVERT DIMENSIONS GIVEN IN FEET TO METERS, MULTIPLY BY 0.3048.
TO CONVERT DIMENSIONS GIVEN IN CFS TO CU M/S, MULTIPLY BY 0.0283.

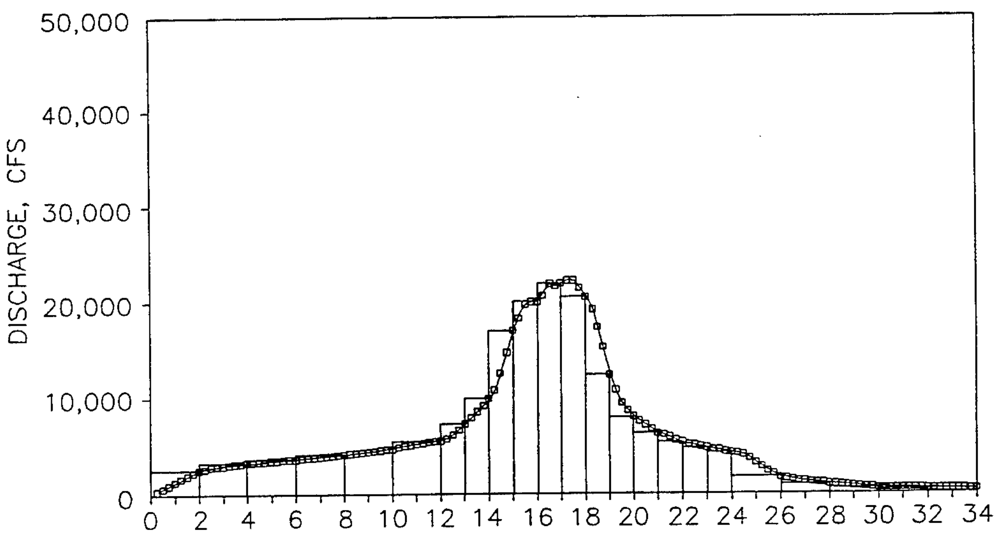


BOTTOM VELOCITIES
TYPE 7 DESIGN, SAN JUAN CREEK
Qsj - 17,000 CFS
Qtr - 17,000 CFS

NOTE: VELOCITIES MEASURED 1 FT FROM BOTTOM.
TO CONVERT DIMENSIONS GIVEN IN FEET TO METERS, MULTIPLY BY 0.3048.
TO CONVERT DIMENSIONS GIVEN IN CFS TO CU M/S, MULTIPLY BY 0.0283.



SAN JUAN CREEK HYDROGRAPH



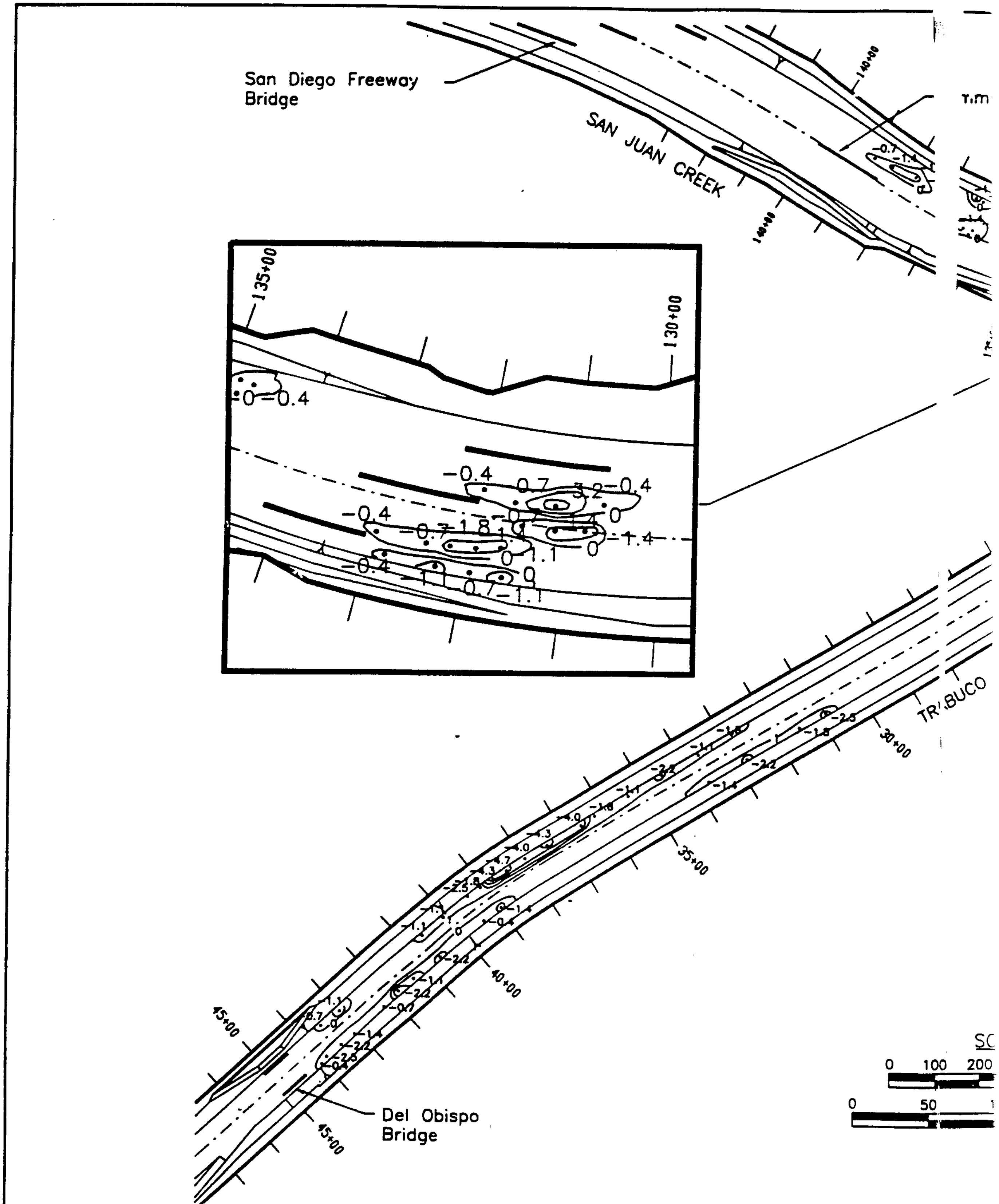
TRABUCO CREEK HYDROGRAPH

NOTE: TO CONVERT DIMENSIONS GIVEN IN FEET TO METERS, MULTIPLY BY 0.3048.
TO CONVERT DIMENSIONS GIVEN IN CFS TO CU M/S, MULTIPLY BY 0.0283.

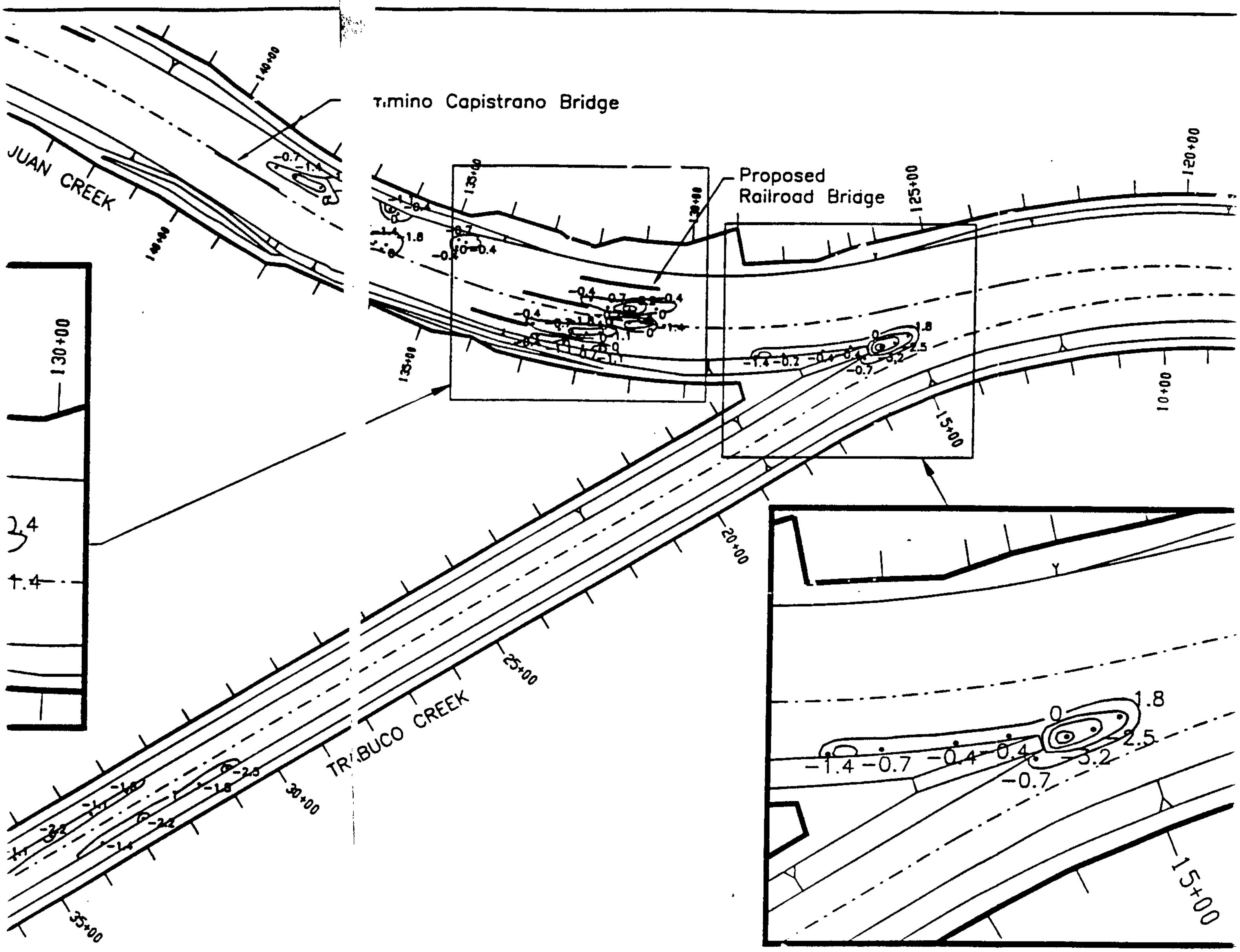
LEGEND

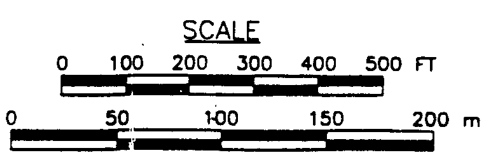
PROTOTYPE DISCHARGE
MODEL DISCHARGE

STORM HYDROGRAPHS



NOTE: CONTOUR LINES AT 1 FT INTERVALS.
TO CONVERT DIMENSIONS GIVEN IN FEET TO METERS, MULTIPLY BY 0.3048.

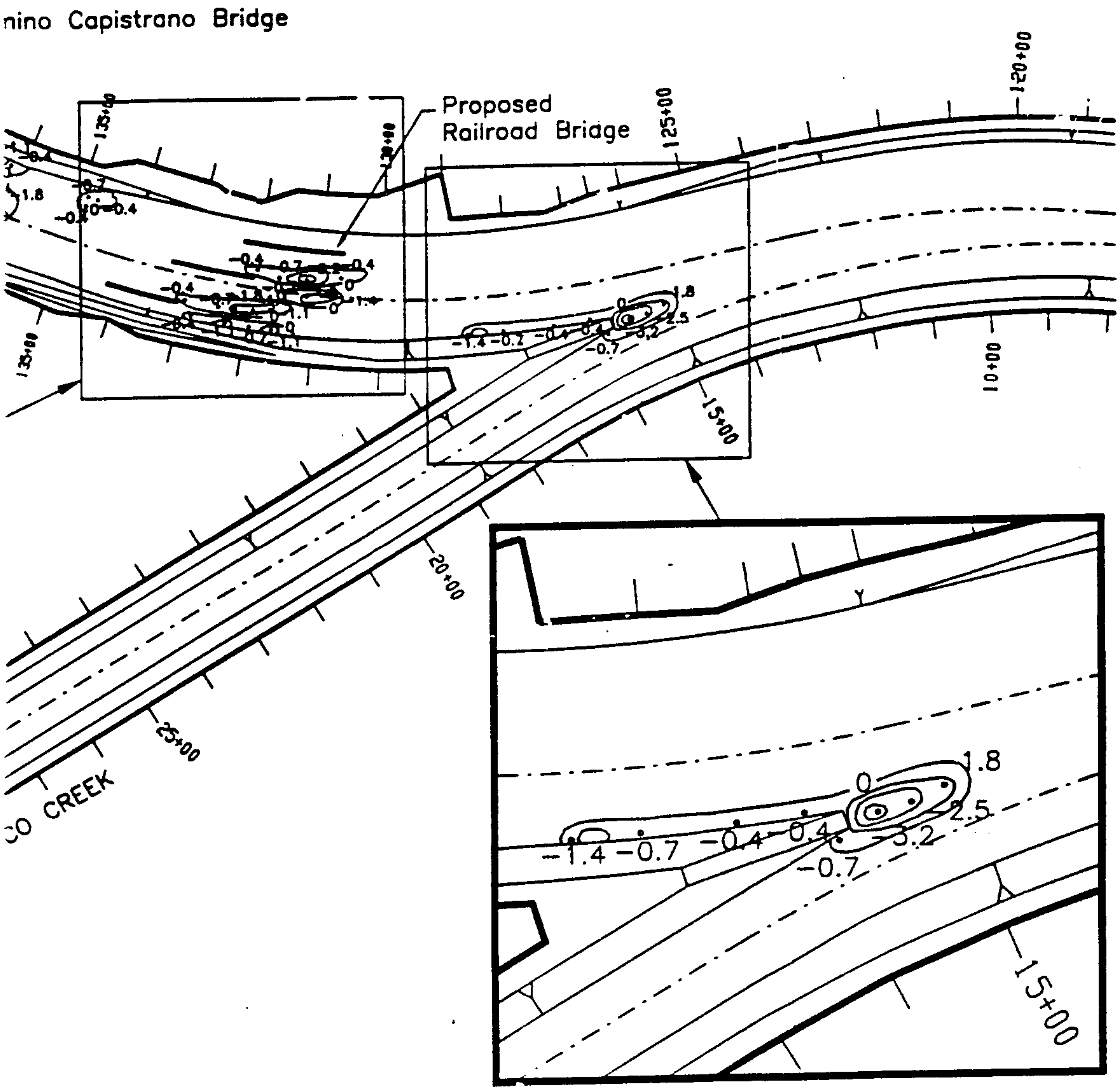


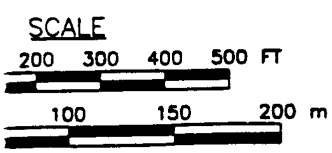


SCOUR ANALYSIS TEST
TYPE 7 DESIGN
GRAVEL BED
LOCAL SCOUR PATTERNS FOR
24-HOUR STORM HYDROGRAPH

ERVALS.
EN IN FEET TO METERS, MULTIPLY BY 0.3048.

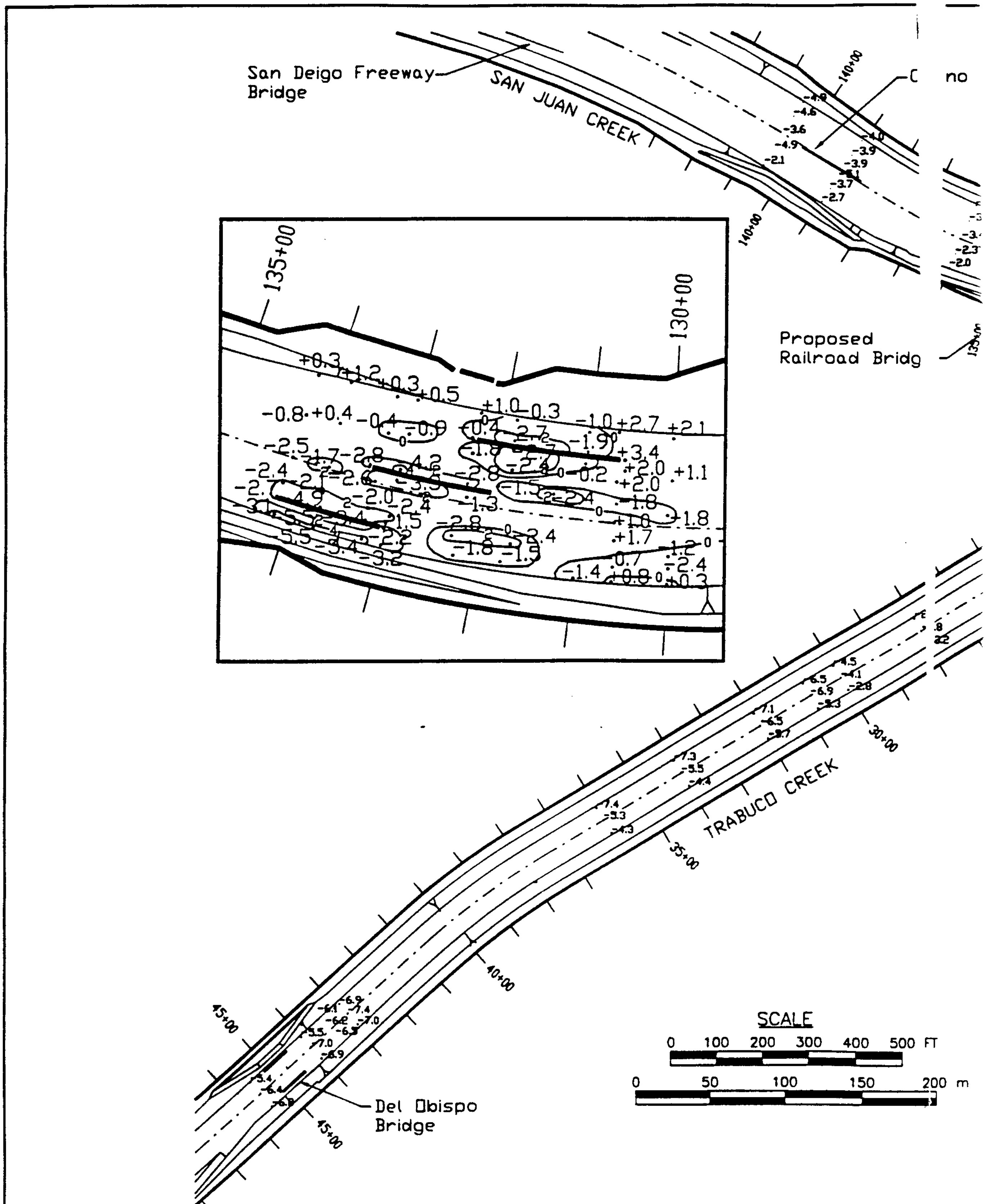
2



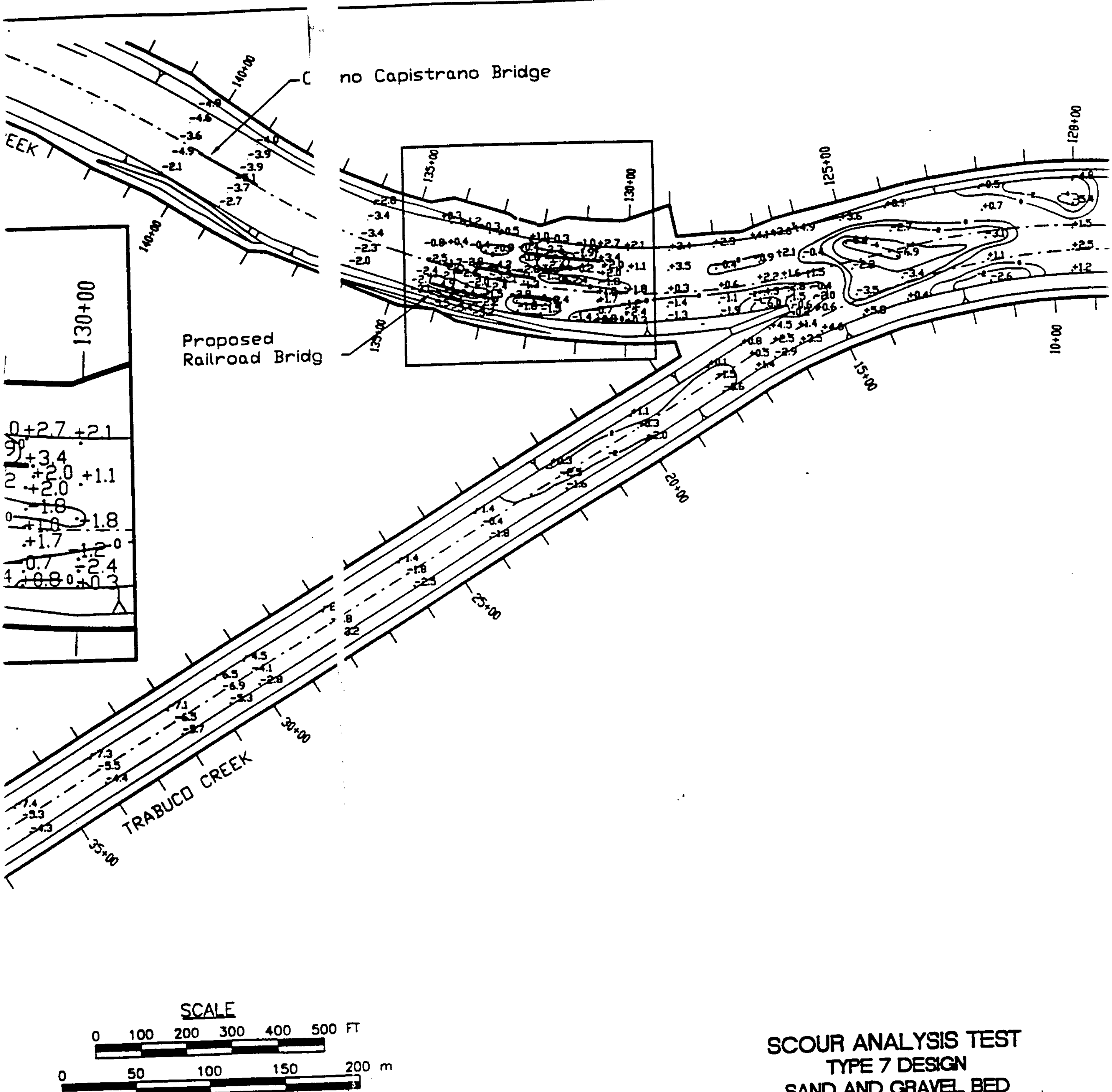


SCOUR ANALYSIS TEST
TYPE 7 DESIGN
GRAVEL BED
LOCAL SCOUR PATTERNS FOR
24-HOUR STORM HYDROGRAPH

3



NOTE: CONTOUR LINES AT 2 FT INTERVALS.
TO CONVERT DIMENSIONS GIVEN IN FEET TO METERS, MULTIPLY BY 0.3048.

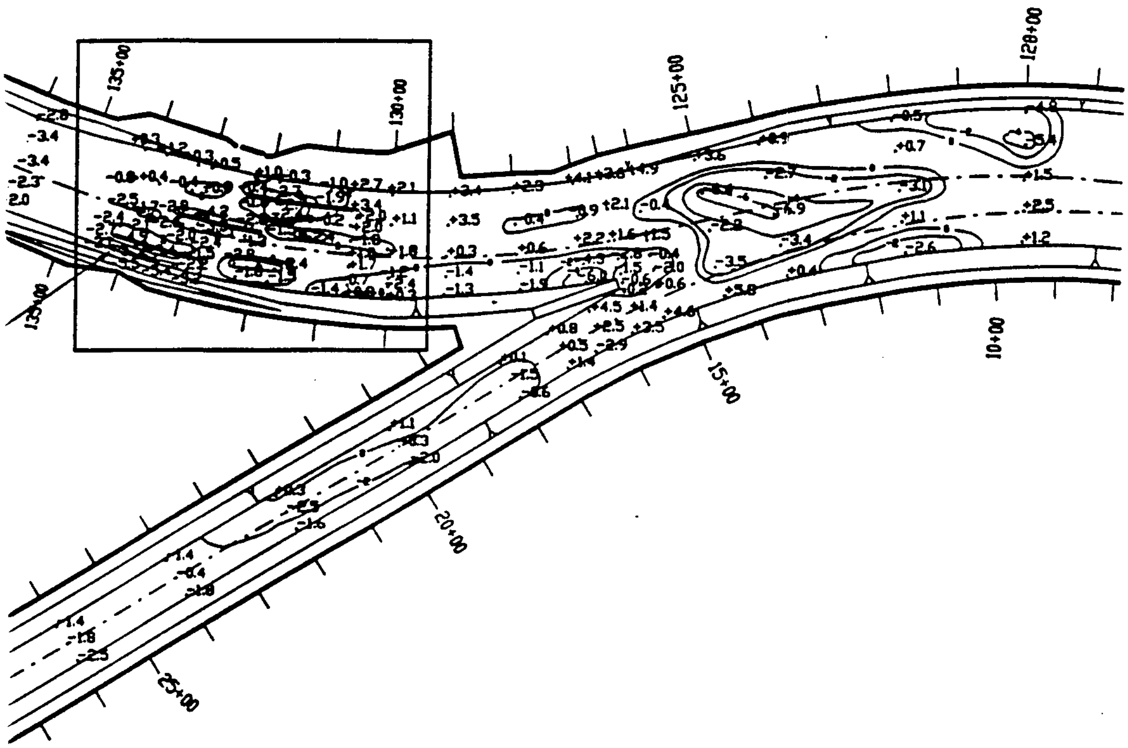


SCOUR ANALYSIS TEST
TYPE 7 DESIGN
SAND AND GRAVEL BED
50-PERCENT FLOW, 24-HOUR DURATION
Q_{sj} = 22,000 CFS
Q_{tr} = 8,000 CFS

.S.
I FEET TO METERS, MULTIPLY BY 0.3048.

(2)

ɿo Capistrano Bridge



SCOUR ANALYSIS TEST
TYPE 7 DESIGN
SAND AND GRAVEL BED
50-PERCENT FLOW, 24-HOUR DURATION
Q_{sj} = 22,000 CFS
Q_{tr} = 8,000 CFS

3

REPORT DOCUMENTATION PAGE

Form Approved
OMB No. 0704-0188

1.AGENCY USE ONLY ***(Leave blank)***

2.REPORT DATE
August 1997

3.REPORT TYPE AND DATES COVERED
Final report

4.TITLE AND SUBTITLE
Model Study of the Confluence of San Juan Creek and Trabuco Creek, Orange County, California; Hydraulic Model Investigation

5.FUNDING NUMBERS

6.AUTHOR(S)
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7.PERFORMING ORGANIZATION NAME(S) AND ADDRESS(ES)
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3909 Halls Ferry Road, Vicksburg, MS 39180-6199

8.PERFORMING ORGANIZATION REPORT NUMBER
Technical Report CHL-97-25

9.SPONSORING/MONITORING AGENCY NAME(S) AND ADDRESS(ES)
County of Orange, Public Facilities and Resources Department
300 North Flowers Street
Santa Ana, CA 92703

10.SPONSORING/MONITORING AGENCY REPORT NUMBER

11.SUPPLEMENTARY NOTES
Available from National Technical Information Service, 5285 Port Royal Road, Springfield, VA 22161.

12a.DISTRIBUTION/AVAILABILITY STATEMENT
Approved for public release; distribution is unlimited.

12b.DISTRIBUTION CODE

13.ABSTRACT ***(Maximum 200 words)***

Tests were conducted on a 1:36-scale physical model of San Juan and Trabuco Creeks to determine the adequacy of the proposed channel improvements, and to determine the effects of the proposed railroad bridge piers on the channel. The model reproduced approximately 5,200 ft (1,585 m) of San Juan Creek, 100 ft (30 m) upstream of the San Diego Freeway with approximately 2,900 ft (884 m) downstream of the confluence (sta 150+00 to 98+00) with Trabuco Creek and 5,100 ft (1,550 m) of Trabuco Creek (station 51+00 to its confluence with San Juan Creek). Flow conditions were observed in both San Juan and Trabuco Creeks for various flow combinations including the design discharges, various unbalanced discharges, and balanced discharges. Later the fixed-bed channel invert was replaced with cohesionless material (fine pea-size gravel) to obtain scour patterns associated with a 24-hour storm hydrograph and 50 percent of peak flow for a 24-hour duration. Because very little scour occurred with the pea-gravel bed, a test was conducted with a 50 percent peak flow for a 24-hour duration using a sand and gravel bed.

The model tests revealed that the proposed design with certain modifications would effectively contain design flow conditions in the San Juan Creek channel improvement project. However, due to the magnitude of water velocities in both creeks during the design flows, protection is needed to prevent erosion of the channel beds. A paved or rock-lined channel

(Continued)

14.SUBJECT TERMS

Access road	Discharge
Bicycle trails	Standing waves
Debris	

15.NUMBER OF PAGES
199

16.PRICE CODE

17.SECURITY CLASSIFICATION OF REPORT	18.SECURITY CLASSIFICATION OF THIS PAGE	19.SECURITY CLASSIFICATION OF ABSTRACT	20.LIMITATION OF ABSTRACT
UNCLASSIFIED	UNCLASSIFIED		

13. (Concluded).

would provide bed stability; however, the model indicated that a rock-lined channel would increase the boundary roughness and cause overtopping of the banks.

Tests were conducted with three proposed designs of the railroad bridge piers and various training wall designs: (a) type 2 design, a four-pier railroad bridge with debris nose, (b) type 3 design, a four-pier railroad bridge with debris nose and a 100-ft- (30-m-) long training wall installed at the confluence, (c) type 4 design, a four-pier railroad bridge with debris nose and a 200-ft- (60-m-) long training wall installed at the confluence, (d) type 5 design, a four-pier railroad bridge with debris nose and a 100-ft- (30-m-) long training wall positioned at a 10-deg (0.174-rad) angle with the nose of the confluence, (e) type 6 design, a three-pier railroad bridge with debris pier nose extensions concentric to the center line of the channel, and (f) type 7 design, a three-pier railroad bridge with debris nose without the pier extensions.

Unsatisfactorily flow conditions were observed in both San Juan and Trabuco Creeks during all fixed-bed tests and were due to the standing waves generated by the bridge piers, bike trails, and access roads. Flow separation occurred in the model and contributed to the generation of standing waves that extended diagonally across the channel. Depth of flow along the railroad bridge piers tended to increase at the nose of the piers and then decrease just downstream of the nose. This change in flow depth caused the velocities along the piers to significantly increase just downstream of the nose and also contributed to the generation of standing waves. The various training walls installed at the confluence did not significantly improve hydraulic performance and caused the flow in San Juan Creek to overtop its banks.

The scour analysis test using 50 percent of peak flow for a 24-hour duration and a sand and gravel bed showed the sediment moving downstream in rolling and sliding motions at velocities slightly less than the flow. Standing waves were observed throughout the model and appeared to be similar to standing waves associated with flow that forms antidunes in the bed material. The scour analysis test revealed that there was a general degradation of the bed material in both San Juan and Trabuco Creeks. However, a buildup of sediment was observed in Trabuco Creek at the confluence and was caused by a "backwater" effect in the flow. Scour along the outside curve of the channel was observed in San Juan Creek as well as deposition along the inside curve of the channel. Armoring of the sand bed was beginning to establish upstream and around the railroad bridge piers and along the outside curve of the channel in San Juan Creek. Elongated scour patterns resembling wake erosion were observed downstream of the railroad bridge piers and were caused by eddies generated by changes in the flow direction around the bridge piers. Scour holes along each side of the piers and between the piers were also observed resulting from the pileup of water on the upstream edge and subsequent acceleration of flow around the nose of the pier. The scour analysis tests conducted are qualitative assessments of the channel's potential scour problems.

The modifications required to provide adequate protection during the design flow consist of (a) paving the channel's invert and side slopes with concrete where supercritical flow is expected in the channel, to eliminate scour in both channels, (b) reshaping the channel's invert slope to create a gradual transition between sta 145+00 and 130+00 and to reduce the magnitude of the standing waves, (c) relocating the access roads downstream of all bridges to prevent possible bridge "pressurization," and (d) removing the grouted rock "wings" on Trabuco and San Juan Creeks to reduce the magnitude of the oblique standing waves.